Appendix 3
Ecological

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Acid Precipitation**
Description of stressor	The air pollutants sulfur dioxide and nitrogen oxides are acidic. They can be distributed through the air over hundreds of kilometers before being deposited on land.
Stressor-specific impacts considered: Biological integrityµ Biodiversity Habitat/ecosystem health Ecosystem function	Acid deposition can cause the acidification of lakes, reservoirs and streams, resulting in damage to fish and other biota. Studies have shown that acid deposition has caused increased cation leaching from some hard wood ecosystems, and this leaching may affect the health of those systems. Although sulfate is the primary anion causing base cation leaching, nitrate is a significant contributor in watersheds that are nearly nitrogen –saturated as a result of acid deposition (National Acid Precipitation Assessment Program, 1998). The compositional properties of foliage may also be altered by acid deposition, resulting in changes in organic matter turnover and nutrient cycling. The sensitivity of hardwood soils to acid deposition is largely controlled by inherent properties, climate, and land use. However, tools to assess present conditions or susceptibility to nutrient depletion are not readily available or widely applicable (National Acid Precipitation Assessment Program, 1998).
Key impacts selected (critical ecological effects)	In New Jersey, the main impacts seem to be affects on aquatic ecosystems, although some forest systems are also affected.
Exposure Assessment	
Exposure routes and pathways considered	Acid deposition occurs through deposition in rain, snow and other precipitation, as well as through dry particulate deposition.
Population(s)/ecosystem(s) exposed statewide	All ecosystems are exposed statewide.
Quantification of exposure levels statewide	Acid precipitation is monitored in New Jersey at the Washington Crossing State Park, at the Lebanon State Forest, and at Ancora. The pH of precipitation has averaged about 4.4 at all of these sites as since the mid-1990s. This is an improvement over the 1980s and early 1990s, when the pH of precipitation averaged about 4.3 at all of these sites. At Washington Crossing State Park, sulfate deposition in precipitation averaged about 25 kg/hectare/yr. from the mid-1980s through the mid-1990s. Since the mid-1990s, sulfate deposition in precipitation has averaged about 20 kg/hectare/yr. (NJ DEP, 1998). Dry deposition is not included in these measurements, so total sulfate deposition is higher.
Specific population(s) at increased risk	Streams and lakes with good buffering capacity are somewhat protected from the effects of acid deposition. In New Jersey, 31 streams and 32 lakes and reservoirs were sampled in 1981 to determine their susceptibility to acid

	Jersey, 31 streams and 32 lakes and reservoirs were sampled in 1981 to determine their susceptibility to acid deposition. Most of the streams were found to have substantial buffering capacity, but several lakes and reservoirs had very limited buffering capacity (Faust and McIntosh, 1986). Some Pinelands streams are experiencing acidification, and several species of conifers in the Pinelands (McDonald's Branch) have had stunted growth, attributed to acid deposition. Red spruce in the Delaware Water Gap National Recreation Area have also been affected (Radis, 1986). Effects on terrestrial vegetation elsewhere in the state have not been found (Brennan, 1986). Trout are especially sensitive to acidic conditions, and their reproduction has occasionally been reduced and halted in New Jersey (Kittatinny Ridge in northwestern NJ, and in Van Campens Brook) following acidic shocks from the melting of highly acidic snows (Sprenger and McIntosh, 1986; Stansley, 1986).	
Quantification of exposure levels to population(s) at increased risk		
Dose/Impact-Response **Assessment**		
Quantitative impact-assessment employed	Sulfate deposition of 20 kg/hectare/yr. has been established as the "Aquatic Effects Level." However, streams and lakes with significant buffering capacity are somewhat protected from the effects of acid deposition. For this reason, the risk assessment is based primarily on observation of reduced pH in streams and lakes and on observed effects on aquatic species, rather than the amount of deposition per se.	
Risk Characterization Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)	Studies indicate that some hardwood ecosystems are close to nitrogen saturation. Nevertheless, in general, the health of eastern hardwood forests has not been shown to be adversely affected by acid deposition. However, broad-scale monitoring has not been conducted to confirm this finding (National Acid Precipitation Assessment Program, 1998).	
		Score

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Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	Acid deposition has an adverse effect on the structure and function of some ecosystems. While all affected habitats are intact and functioning, population abundance of some sensitive species are reduced (3)	3
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Acidic deposition is a continual process, and its effects are often and continuing (4).	4
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	While the entire state receives acidic deposition, only the sensitive systems and populations are significantly impacted. Overall, perhaps 5 – 10% of the state's habitats are impacted (2)	2
	Total	24

Assessment of uncertainties in this assessment (H,M,L) and brief description	M.
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	L. Acid deposition has been studied extensively. While the precise impact of acid deposition on ecosystems is difficult to measure in many cases, it is unlikely that new studies will result in major changes in our understanding of the impacts.
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	0. Sulfur and nitrogen emissions may decrease somewhat with improved controls on fossil fuel combustion. On the other hand, increases in energy use and fuel use will tend to increase the emissions of sulfur and nitrogen.
Potential for catastrophic impacts (H,M,L) and brief description	L
Link to other Work Groups (e.g., socioeconomic impacts)	Socio-economic impacts: Acid deposition can corrode structures in urban areas.
Extent to which threat is currently regulated or otherwise managed	Sulfur and nitrogen emissions are controlled by the US Clean Air Act.
Barriers to restoration	
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	H. The main source is sulfur emissions from coal-burning power plants
Small business industry	
Transportation	H – Combustion of fossil fuels is a source of nitrogen oxides.
Residential	
Agriculture	
Recreation	
Resource extraction	
Government	
Natural sources/processes	
Orphan contaminated sites	
Diffuse Sources	
Sediment sinks	
Soil sinks	
Non-local air sources incl. deposition	

Biota sinks	

Summary Statement: The air pollutants sulfur dioxide and nitrogen oxides are acidic. Acid deposition can cause the acidification of lakes, reservoirs and streams, resulting in damage to fish and other biota. In New Jersey, the main impacts seem to be affects on aquatic ecosystems, although some forest systems are also affected.

Acid precipitation in New Jersey is less severe than in the 1980s and early 1990s.
Some Pinelands streams are experiencing acidification, and several species of conifers in the Pinelands (McDonald's Branch) have had stunted growth, attributed to acid deposition. Red spruce in the Delaware Water Gap National Recreation Area have also been affected. Effects on terrestrial vegetation elsewhere in the state have not been found. Trout are especially sensitive to acidic conditions, and their reproduction has occasionally been reduced and halted in New Jersey (Kittatinny Ridge in northwestern NJ, and in Van Campens Brook) following acidic shocks from the melting of highly acidic snows.

Overall, acid deposition has an adverse effect on the structure and function of some ecosystems. While all affected habitats are intact and functioning, population abundance of some sensitive species is reduced.

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Statewide Analysis of Threat

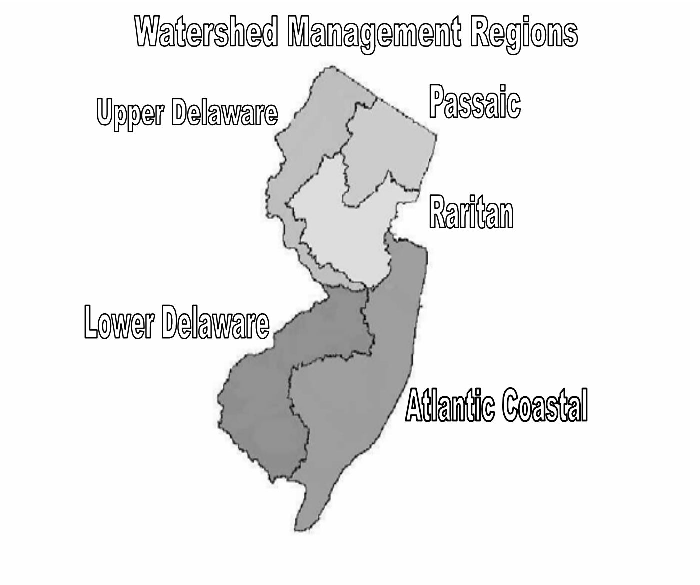
Threat = Acid Precipitation

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	4	3	36
Marine Waters	2	0.1	1	0.1
Wetlands	3	4	2	24
Forests	3	4	2	24
Grasslands	2	2	1	4
			Total Score	88.1
			Average Score (Total ÷ 5)	17.6

Risk by Watershed Management Region

THREAT = Acid Precipitation	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	M	NA	M	M	L
Passaic	M	NA	L	M	L
Raritan	L	NA	L	L	L
Atlantic	M	NA	M	M	L
Lower Delaware	M	NA	M	M	L
Region/Watershed (secondary)					
Urban	NA	NA	NA	NA	NA
Suburban	L	L	L	L	NA
Rural	M	NA	M	M	L

H=high, M=medium, L=low, NA = not applicable


Watershed Management Regions
Upper Delaware
Passaic
Raritan
Lower Delaware
Atlantic Coastal

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Arsenic**
Description of stressor	Arsenic occurs naturally in soils, principally as an oxide or sulfide but also in its elemental form, and is the 20[th] most abundant element in the Earth's crust. Arsenic is a semi-metal with oxidation states of 3-, 0, 1+, 2+, 3+, or 5+. The most common oxidation states of As in soil and water are 3+ and 5+. Compounds where As is in the 3+ oxidation state are generally more toxic than compounds where As is in the 5+ oxidation state. Arsenic metal (oxidation state 0) and As metal alloys are considered less toxic than oxidized forms. The valence state in nature changes with redox potential, and arsenic in soil and wetlands is subject to methylation and to complex biological reactions. The arsenic (As) cycle in the marine environment is known to be sensitive to biological activity, as well (Michel, et al. 1998). Bacteria, molds, and fungi may alter the valence state of arsenic by methylation-demethylation, absorption, complexation, and redox processes. Microorganisms may influence its bioavailability, toxicity, mobility in soil and aquatic ecosystems. Arsine gas may be released through the action of microorganisms from soils containing arsenate, arsenite, methylarsenate and dimethylarsenate (Morrison, et al., 1999). For example, with a natural source of arsenic from geothermal inputs, Wilkie, et al. (1998) found that arsenic redox cycling in Hot Creek, a tributary of the Owens River, source waters of the Los Angeles Aqueduct in the Sierra Nevada mountains of California, is biologically mediated. Downstream from the elevated arsenic input, rapid in-stream oxidation of As (III) to As (V) occurred. In laboratory studies, oxidation did not occur after sterile filtration or after the addition of antibiotics, which indicates that bacteria attached to submerged macrophytes are mediating the rapid As (III) oxidation reaction. In addition to natural sources, arsenic can be added to soil from human activities such as mining, smelting, and combustion of fossil fuels. Arsenic has also been widely used as an agricultural pesticide (Murphy & Aucott, 1998). A U.S. EPA report with information regarding the emissions, fate, and transport of utility Hazardous Air Pollutants includes arsenic. The primary components of this report are: (1) a description of the industry; (2) an analysis of emissions data; (3) an assessment of hazards and risks due to inhalation exposures (4) assessments of risks due to multipathway (inhalation plus non-inhalation) exposures; and (5) a discussion of alternative control strategies (USEPA, 1998). Substantial atmospheric transport of arsenic occurs. Rautio et al. (1998) measured arsenic in Scots pine needles collected from transects across Finnish Lapland and the Kola Peninsula in Russia. The effect of the emissions from the smelters was clearly seen in the needle chemistry up to 50 km away from smelters and was still perceivable over 100 km away. Blown dust containing arsenic can be a hazard. In New Jersey, the draining of Union Lake in order to repair its dam, exposed sediments heavily contaminated by arsenic from Vineland Chemical Corp., a pesticide manufacturer on the Blackwater Branch, a tributary of the Maurice River upstream from Union Lake.

That dust from former aquatic ecosystems can present a risk is also illustrated by experience with Owens Lake in California, which became essentially dry by the 1920s after the Los Angeles Aqueduct was constructed and diversion of water from the Owens River began. Frequent dust storms at Owens Lake produce clouds of efflorescent salts which present human health hazards as a result of their small particle size and elevated concentrations of As (Levy et al., 1999).

Risks from ingestion of arsenic in soil cannot be extrapolated from studies of soluble arsenate or arsenite in drinking water because of differences in chemical form, bioabailability, and excretion kinetics. Some researchers have argued that risks from arsenic in soil are generally lower than what would be calculated using default toxicity values for arsenic in drinking water (Dudka & Miller, 1999). On the other hand, Williams et al., (1998) studied the post-ingestion bioavailability of arsenic (As) in alluvial soil and mineral waste tailings using a physiologically-based extraction test and concluded that contaminated soil ingestion constitutes a more significant As exposure pathway than recognized previously. Their analyses of alluvium samples indicated an average stomach absorption of 11.2% (of total soil As). Gross absorption increased to 18.9% following translocation through a simulated small-intestine regime. Higher gross absorption (35.7%) was recorded during analysis of a flotation waste sample holding c. 2% total As.

Human Health Considerations
Human exposures to As have been strongly associated with increases in skin, lung, and internal cancers, but As does not typically cause tumors in standard laboratory animal test protocols. In addition, exposure to As in drinking water has been associated with the noncarcinogenic effects such as diabetes, peripheral neuropathy, and cardiovascular diseases. Although arsenite [As(III)] can inhibit more than 200 enzymes, events underlying the induction of the noncarcinogenic effects of arsenic are not understood. With respect to carcinogenicity, arsenic can affect DNA repair, methylation of DNA, and increase radical formation and activation of the Protooncogene c-myc, but none of these potential pathways have widespread acceptance as the principal etiologic event (Abernathy et al., 1999).

Microorganisms
Bacterial plasmids encode resistance systems for toxic metal and metalloid ions including AsO_2^- and $AsO^3{}_4^-$. Most resistance systems function by energy-dependent efflux of toxic ions. A few involve enzymatic (mostly redox) transformations. Some of the efflux resistance systems are ATPases and others are chemiosmotic ion/proton exchangers. The arsenic resistance system transports arsenite [As(III)], alternatively with the ArsB polypeptide functioning as a chemiosmotic efflux transporter or with two polypeptides, ArsB and ArsA, functioning as an ATPase. The third protein of the arsenic resistance system is an enzyme that reduces intracellular arsenate [As(V)] to arsenite [As(III)], the substrate of the efflux system (Silver, 1998).

Plants
In wetland surface sediments of Louisiana, arsenic concentrations are elevated because of a wide use of inorganic arsenicals as cotton desiccants and of organic arsenicals as herbicides in rice-producing areas. Beside this, arsenic levels are even higher in the region of water discharge associated with petroleum hydrocarbon recovery operations. The uptake, potential bioavailability and phytotoxicity of As to important wetland plant species, *Spartina alterniflora* and *Spartina patens* growing in the vicinity of such discharge sites were studied by Carbonell and co-workers (1998). Arsenic uptake by the two perennial coastal marsh grasses growing in hydroponic conditions was measured in relation to the chemical form and concentration of arsenic added to nutrient solution. Arsenic phytoavailability and phytotoxicity were primarily determined by its chemical form present in the nutrient solution, though arsenic concentration also influenced both availability and toxicity.

	Organic arsenicals and As(III) were the most phytotoxic forms to marsh grasses when plant growth was considered. Arsenic uptake and transport in plant were species-specific. Phytoavailability of As followed the trend DMAA << MMAA approximately equal to As(V) < As(III). Upon absorption, inorganic arsenicals and MMAA were mainly accumulated in the root system, while DMAA was readily translocated to the shoot. DMAA was the most phytotoxic compound to *Spartina patens* (Carbonell-Barrachina, et al., 1998). The high phytotoxicity of the MMAA treatments could have been related to the significant reductions in the concentrations of several essential macronutrients, causing the highest Na root concentrations and simultaneously the lowest plant K levels (Carbonell, et al., 1998). **Invertebrates** The toxicity and accumulation of arsenate was determined in the earthworm *Lumbricus terrestris* in soil from different layers of a forest profile. Toxicity increased fourfold between 2 and 10 days. Edaphic factors (pH, soil organic matter, and depth in soil profile) also affected toxicity with a three fold decrease in the concentration that causes 50% mortality with increasing depth in soil (from 0-70 mm to 500-700 mm). In long-term accumulation studies in soils dosed with a sublethal arsenate concentration (40 units?? mu g/g dry weight), bioconcentration occurred after day 12, after which earthworm concentrations rose steadily above the soil concentration, with residues in worms three fold higher than soil concentrations by the termination of the study (23 d) (Meharg, et al., 1998) In earthworms and soil collected from six sites in Styria, Austria, total arsenic concentrations ranged from 3.2 to 17.9 mg/kg dry weight in the worms and from 5.0 to 79.7 mg/kg dry weight in the soil samples. There was no strict correlation between the total arsenic concentrations in the worms and soil. The major arsenic compounds detected in the extracts of the earthworms were arsenous acid and arsenic acid. Arsenobetaine was present as a minor constituent, and traces of dimethylarsinic acid were also detected. Two dimethylarsinoylribosides were also identified in the extracts. This is the first report of the presence of dimethylarsinoylribosides in a terrestrial organism (Geiszinger, et al. 1998). Three freshwater mollusc species were collected at the point source of the heavy metal pollutants and analyzed for the heavy metal contents in their tissues and shells. Two of the mollusc species (*Brotia costula and Melanoides tuberculata*) are purely freshwater species while the *Clithon* sp. nr retropictus is able to survive in fresh and brackish water environments. The level of As in the tissues of *Brotia costula* and the *Clithon* sp. was much higher than the permissible level for human consumption (Lau, et al., 1998). Accumulation of arsenic in the tail muscle, gills, midgut gland, exoskeleton, and remaining tissues After 16 d, C. crangon fed arsenate, trimethylarsine oxide, or arsenobetaine had accumulated arsenic in their tail muscle to levels similar to 2-, 2-, or 40-times, respectively, that of the control group. On a whole animal basis, C. crangon retained similar to 1.2% of the arsenate, 1.6% of the trimethylarsine oxide, and 42% of the arsenobetaine consumed over the first 16 d of exposure, with roughly half present in the tail muscle in each case. of the common shrimp, *Crangon crangon* (L.), was found to depend on the chemical form of the arsenic and the route of exposure. Data obtained support the view that the direct uptake of arsenobetaine from sea water does not make a significant contribution to the relatively high concentrations of this compound in marine crustaceans, and that food is the primary source (Hunter, et al., 1998). Mussel Watch results from coastal waters of the United States for 1986 through 1996 show no overall trend for arsenic (O'Connor, 1999). Results of laboratory and field studies conducted to determine the rates of release for Cu, Cr and As from CCA-C treated southern yellow pine in estuaries showed that the release of Cu, Cr and As was continuous throughout the 90 day leaching period and, in general, the leaching was highest for Cu and lowest for Cr. Long-term As leaching rates increased in wood where CCA-C retention levels were <35 kg m^3 (Breslin & Adler-Ivanbrook, 1998).

	Blue mussels (*Mytilus edulis*) exposed to CCA-C-treated wood in laboratory flow-through sea table and field exposure experiments showed few significant differences in condition index, dry weight, and length between CCA-C-exposed and control mussels. In addition, no statistically significant differences in mortality were found between the mussels exposed to CCA-C-treated and nontreated SYP in the laboratory flow-through sea table and field exposure experiments. The lack of Cu, Cr, and As uptake from CCA-C-treated SYP was attributed to the low, although continuous, rate of release of these elements from CCA-C-treated wood and to the experimental design, which allowed continuous flushing, prohibiting the accumulation of these elements in the water surrounding the mussels. (Adler-Ivanbrook & Breslin, 1999). Weis et al., (1998) found species richness, Shannon-Wiener diversity index, and biomass of the benthic community are affected by leaching from chromated copper arsenate-treated wood bulkheads. At two of the sites there was evidence for secondary reduction of the community out further to 3 or 10 m, where the metals in the fines were lower but the percent fines was greatly increased. At all the other sites, impacts were generally limited to 0 and 1 m. The lack of reduction at further distances at the other sites is attributed to factors such as the age of the bulkheads, high energy of the environment, or nature of the sediments at those sites. **Amphibians** Tadpoles collected from waters immediately downstream from a site contaminated during 53 years of industrial production of arsenic based cotton defoliants contained elevated levels of arsenic. The mean concentration of As (6.87 p.p.m. wet weight) in cricket frog (*Acris crepitans*) tadpoles was the highest ever reported in tadpoles. The concentrations of As found in the tadpoles in this study might be toxic to predators. Mortality of turtles showing symptoms linked to chronic exposure to As. A downstream lake showed abundant tadpoles and turtles but no snakes, which may indicate that their sensitivity for exposure to arsenic and the other existing contaminants is greater than that of frogs and turtles (Clark et al., 1998). **Fish** In winter flounder (*Pleuronectes americanus*), coagulative necrosis, single cell necrosis and haemorrhagic necrosis showed positive associations with hepta- to nonachlorobiphenyls and arsenic, zinc, nickel, and mercury, and negative associations with high molecular weight, combustion-derived PAHs and DDT compounds and metabolites (Chang et al., 1998). Juvenile winter flounder (*Pleuronectes americanus*) from a Long Island Sound site within the Niantic River region contain elevated levels of liver As. Previous work in mammals suggests that a reduced species of As, $NaAs^{3+}$), is a potent metallothionein (MT) inducer. In winter flounder, arsenic rapidly induced MT protein within 24 h of exposure, although it was not as potent as $CdCl_2$ (Jessen-Eller & Crivello, 1998). **Birds** Arsenic was detected in only 13 of 104 eggs of Interior Least Terns (*Sterna antillarum athalassos*) from Kansas, Nebraska, South Dakota, North Dakota, and Montana from 1992 through 1994. Thus, arsenic was unlikely to effect Least Tern reproduction in the region, even though nesting success reported for the study area was not sufficient to support the local populations. Nest flooding and predation probably were the major causes of low recruitment (Allen, et al., 1998). One of the most important bird breeding and over wintering sites in the west of Europe, the Coto Donana, was severely impacted by the release of 5 million cubic meters of acid waste from the processing of pyrite ore. The waste entered ecologically sensitive areas of the park (including breeding areas for internationally endangered bird species) causing sustained pH decreases from pH 8.5 to 4.5 and resulting in massive metal contamination of the impacted ecosystem. The contaminating sludge waste contained arsenic at 0.6%, lead at 1.2% and zinc at 0.8% on a dry weight basis. The acid conditions facilitated the solubilization of these metals, leading to water concentrations lethal for aquatic wildlife. The accident caused considerable fish and invertebrate kills and has severe consequences for the protected bird species dependent on the impacted habitats and adjacent areas. (Pain, et al., 1998).
	Mammals

	Arsenic is a ubiquitous contaminant of many toxic waste sites around the country and experimental animal trials have indicated that arsenic may be immunotoxic to laboratory rodents. Savabieasfahani, et al. (1998) used the herbivorous cotton rat (*Sigmodon hispidus*) a wild rodents residing on many of these toxic waste sites to assess direct effects of low-level arsenic exposure on immune function. Such effects were minimal (a moderate depression in the in vivo cell-mediated immunity assay) and may not be clinically relevant with regard to susceptibility to disease in the wild. Studies by Nemec et al. (1998) revealed an absence of dose-related effects in both mice and rabbits at arsenic exposures that were not maternally toxic. In mice, 7.5 mg/kg/d was the maternal No-Observed-Adverse-Effect-Level (NOAEL); the developmental toxicity NOAEL, while less well defined, was judged to be 7.5 mg/kg/d. In rabbits, 0.75 mg/kg/d was the NOAEL for both maternal and developmental toxicity. DeSesso at al. (1998) claim that while studies of reproductive and developmental toxicity have purported to show an association between exposure of pregnant laboratory animals to arsenic compounds and the occurrence of offspring with cranial neural tube defects, particularly exencephaly such investigations in experimental animals are inadequate for human risk assessment purposes. Cranial neural tube defects are induced in rodents when arsenic exposure has occurred early in gestation (on Days 7 [hamster, mouse], 8 [mouse], or 9 [rat]), but only when arsenic exposures were in single doses, by injection directly into the venous system or the peritoneal cavity, so high as to be lethal (or nearly so) to the pregnant animal. Even massive oral exposures do not cause increases in the incidence of total gross malformations. These researchers concluded that under environmentally relevant exposure scenarios (e.g., 100 ppm in soil), inorganic arsenic is unlikely to pose a risk to pregnant women and their offspring. Arsenic toxicosis is reported in a variety of animal species. It occurs most commonly in cattle and ranks second only to lead as a cause of heavy metal poisoning. A case of arsenic toxicosis was described that was attributable to ingestion of ashes from burned posts treated with an arsenic-containing preservative. Burning of the posts concentrated the arsenic and rendered lethal a product normally used around livestock. Lack of normal salt supplementation to the herd was conducive to pica-like behavior and ingestion of toxic ashes (Hullinger, et al., 1998).
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	Potential impacts occur on a large number of plant and animal species, since arsenic has been used as a herbicide and animal pesticide across major phyla from protists, to molluscs, arthropods, and vertebrates. Arsenic has the potential to impact biological integrity, to adversely affect biodiversity and thus to negatively impact ecosystem health and function.
Key impacts selected (critical ecological effects)	Soil organisms, aquatic ecosystems. Biodiversity, biological integrity and ecosystem health and function.
Exposure Assessment	
Exposure routes and pathways considered	Atmospheric deposition to soils and aquatic ecosystems, direct application as pesticides to soil, accidental release from manufacturing facilities, absorption in aquatic ecosystems, ingestion from soil or sediment, food web transfer. Stormwater and other discharges.
exposed statewide	Because arsenic is naturally occurring but has also been so widely used, particularly as a herbicide and pesticide in New Jersey, virtually all ecosystems have been exposed, with many plant and animal populations at risk.

Quantification of exposure levels statewide	New Jersey Water Resources Data for New Jersey (DeLuca, et al. 1998) gives a range of <1 to 3 µg/L for arsenic in surface water and values in sediment from <1 to 12 mg/kg, for samples from 42 stations in the State. NOAA data: Passaic River sediment, 220 samples, average of 12.7 mg/kg with a range of 1.2 to 67 mg/kg. Adams et al., 1998 data (R-EMAP) for the Newark Bay complex (Newark Bay, Arthur Kill, Passaic and Hackensack Rivers): area-weighted means for Arsenic in sediment was 25.5 mg/kg; 12% of the area exceeded the Effects Range-Median (ER-M) value for Newark Bay complex (and approximately 42% of the NY-NJ harbor exceeded the Effects Range – Low (ER-L) for arsenic) Estimates for average natural background concentrations of arsenic in soil are in the neighborhood of 5 to 15 mg/kg, but because some soils are high in arsenic containing minerals, "natural background" can be quite variable. For background values Lemo, et al. (1983) give a range of 0.1 to 42 mg/kg; a more recent paper by Dragun and Chiasson (1991), reports that U.S. soils background concentrations range from <1 to 97 mg/kg, with the arithmetic mean of 7.2 mg/kg. Measurements of dissolved As were made in the tidal freshwater Delaware River at four sites in July 1991, January 1992, and March 1992. Concentrations of dissolved As were generally higher in July than in March or January. Based on estimates of similar rivers, Arsenic may be moderately enriched in Delaware River seston compared to other rivers draining the same geological provinces (Riedel & Sanders (1998). In urban center within the Piedmont Region of New Jersey, arsenic was detected in 13% of soil samples at concentrations above state-proposed cleanup criteria (Wong & Sanders, 1998). Estimates of the amounts of arsenical pesticides historically applied to cropland, turf and golf courses in New Jersey were made to the county level. Specifically, estimates of the amounts of lead arsenate and calcium arsenate pesticides are presented. In New Jersey it is estimated that 49,000,000 pounds (lb.) of lead arsenate and 18,000,000 lb. of calcium arsenate were applied to soils in the state from 1900 to 1980. Of this, a cumulative total of approx. 15,000,000 lb. of arsenic was applied during this time frame. It is important to assess the approximate quantities of arsenical pesticides in New Jersey because soils in the state have been shown to contain elevated levels of lead and arsenic. In order to target soil-monitoring efforts, it is important to determine which counties are most likely to have received treatment. Furthermore, exposure assessments can be better evaluated when estimates of application for these pesticides are available (Murphy & Aucott, 1998). There are many sites in New Jersey with arsenic soil concentrations exceeding the recommended soil clean-up level of 20 mg/kg. Apparently, natural background levels in some parts of the State sometimes exceed 20 mg/kg, because of high arsenic containing minerals, such as glauconite. Since arsenical pesticide use was very extensive, particularly from the 1930's well into the 1960s, it may be difficult to distinguish natural from anthropogenic arsenic.

	From an investigation of sites with potentially naturally occurring elevated background arsenic levels, in a file maintained by Kevin Schick (1999) of DEP's Site Remediation Program, arsenic concentrations are given for a number of locations in central and southern New Jersey. In Burlington County, in a site in Mt. Laurel Township, one sample had a maximum concentration of 260 mg/kg, the geometric mean of 130 samples taken at the site was 17.7; although some farming occurred on this site, the arsenic is thought to be natural.
	A number of other sites investigated in Burlington County had arsenic in soil in excess of 20 mg/kg. Camden County samples ranged to 89 mg/kg, and at a site in Gloucester County, the mean concentration of 10 samples taken at a depth of 24-26 inches below the surface was 41.5 mg/kg. At a site in Mercer County, slated for development, a maximum of 359 mg/kg was found in one sample and confirmed by a duplicate sample. At this site, at a depth of 4-6 feet, the average of 38 samples was 26.5 mg/kg, with 50% of the samples exceeding the guideline of 20 mg/kg. Samples from sites in Monmouth and Middlesex Counties also exceeded the 20-mg/kg guideline, but were determined to result from natural background levels of arsenic. Much higher concentrations of arsenic have been found resulting from anthropogenic sources at some locations in New Jersey. At the Horseshoe Road Superfund site in Sayerville, Middlesex County, sediment samples from the adjacent Raritan River ranged to 2200 mg/kg, and sediment from a downstream marsh location had arsenic concentrations as high as 4030 mg/kg (NJDEP/SRP). In Cumberland County, Vineland Chemical Corp., situated on the Blackwater Branch of the Maurice River, was responsible for massive widespread contamination with arsenical pesticides. Measured arsenic reached as high as 2780 µg/L in surface water samples, 2290 mg/kg in sediments, and 12,500 µg/L in pore water from sediment samples. Inorganic arsenic, as As^{+5}, and As^{+3}, as well as the organic arsenicals, monomethylsrsenic acid, and dimethylarsenic acid were found (Faust, et al., 1983).
Specific population(s) at increased risk	Soil microorganism and invertebrate populations; aquatic plants and animals.
Quantification of exposure levels to population(s) at increased risk	**Background** Average soil background for the State as a whole is probably <10 mg/kg, although some samples with naturally occurring arsenic, in glauconitic formations, have reportedly reached as high as 370 mg/kg. Background in surface water is ~ 1 µg/L, and does not exceed 3 Background in aquatic sediment ranges from <1 to 12 mg/kg. **Benchmarks** NJDEP's soil clean up standard is 20 mg/kg Water quality criteria: freshwater chronic criteria = 190 µg/L, saltwater chronic criteria = 36 µg/L. Sediment: Marine/estuarine - ER-L = 8.2 mg/kg; ER-M = 70 mg/kg. For freshwater sediments the LEL (Lowest effect level) for Arsenic is 6 mg/kg, and the severe effect level (SEL) is 33 mg/kg.
	High Exposure Concentrations

	Surface water - 2780 μg/L Sediments - 4030 mg/kg Sediment Pore Water - 12,500 μg/L	
Dose/Impact-Response Assessment		
Quantitative impact-assessment employed	Instances of such high exposure, as cited above, may be limited to the vicinity of manufacturing or hazardous waste sites; however the widespread application of arsenical pesticides may have contaminated other areas of the State. Thus, although highly uncertain as to aerial extent, the Hazard quotient method, HQ = Env. Conc./Benchmark Conc. gives a rough indication of impact.	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)	HQ can range up to 55.6 and 250 in surface water and sediment pore water, and to 200 in sediments	Score

{tc \l2 "**Score 16.5**}Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: many species threatened/endangered major community change extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: all habitats intact and functioning population abundance and distributions reduced Short time for recovery 2 – Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		2-3
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 Occasional 2 Rare 1 - Possible in the future 0 Unlikely (or 0.1)		3
Size of population(s) and/or extent of the State/habitat affected (magnitude)		2

5- >50% of the State impacted 4- 25-50% of the State impacted 3- 10-25% of the State impacted 2- 5-10% of the State impacted 1- <5% of the State impacted		
	Total Score	12-18
Assessment of uncertainties in this assessment (H,M,L) and brief description	H: While there are hot spots of arsenic, with attendant exposure, it is unknown how widespread, at such high levels, arsenic occurs. On the otherhand, because of abundant sources, atmospheric transport, and widespread anthropogenic use, arsenic is at least a potential threat to many areas of the State.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	H: Data on specific effects on organisms and populations, as well as a better assessment of the distribution of arsenic would help considerably. Needs cited by researchers were: a) AsS metabolism and its interaction with cellular constituents; b) possible bioaccumulation of As; c) interactions with other metals; d) effects of As on genetic material; e) development of animal models and cell systems to study effects of As; and f) a better characterization of human exposures as related to health risks. Some of the barriers to the advancement of As research included an apparent lack of interest in the United States on As research; lack of relevant animal models; difficulty with adoption of uniform methodologies; lack of accepted biomarkers; and the need for a central storage repository for stored specimens.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, –, =, ≡; where + is improvement), and brief description.	++ Phase out of use of arsenic as a pesticide, better controls on atmospheric emissions, and clean up of hazardous waste sites should help limit future exposure	
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L: Low potential for widespread impacts. Leaching of arsenicals from terrestrial sites into aquatic ecosystems, such as occurred at Vineland Chemical, could severely impact a nearby ecosystem.	
Link to other Work Groups (e.g., socioeconomic impacts)	Human Health workgroup should review human cancer and teratogenic potential, in view of widespread occurrence of arsenic in well water in southern New Jersey.	
Extent to which threat is currently regulated or otherwise managed	Cleanups occurring at identified hazardous waste sites. DEP currently investigating extent of arsenic occurrence from use in agriculture. Widespread pesticide use has stopped.	

Barriers to restoration	Fossil fuel burning continues atmospheric contributions.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	H: past pesticide manufacturing, coal fired utilities, etc.
Small business industry	H: pesticide distribution
Transportation	L
Residential	L (although past use probably substantial)
Agriculture	H: widespread past use of arsenical pesticides
Recreation	H: golf course use of pesticides included arsenicals
Resource extraction	L in NJ, very substantial elsewhere, and probably contributes to worldwide atmospheric transport of Arsenic
Government	L (although past use of pesticides on State land was probably substantial)
Natural sources/processes	H: natural occurrence of arsenic in many areas of NJ
Orphan contaminated sites	M
Diffuse Sources	
Sediment sinks	H in specific locations; M statewide

Soil sinks	H in specific locations; M statewide
Non-local air sources incl. deposition	M: Arsenic is globally transported from mining, manufacturing, and fossil fuel burning
Biota sinks	M: Arsenic is apparently cycled fairly rapidly through most animals, not accumulating in tissue; some animals and plants however may take up and sequester some forms of arsenic

Summary Statement: In addition to natural sources, arsenic can be added to soil from human activities such as mining, smelting, and combustion of fossil fuels. Arsenic has also been widely used as an agricultural pesticide. Substantial atmospheric transport of arsenic occurs. Blown dust containing arsenic can be a hazard as occurred in New Jersey, when the draining of Union Lake in order to repair its dam, exposed sediments heavily contaminated by arsenic. Arsenic is a semi-metal with various oxidation states. The most common oxidation states of As in soil and water are 3+, generally more toxic, and 5+. Arsenic metal (oxidation state 0) and As metal alloys are considered less toxic than oxidized forms. The valence state in nature changes with redox potential, and arsenic in soil and wetlands is subject to methylation and to complex biological reactions. Potential impacts occur on a large number of plant and animal species, since arsenic has been used as a herbicide and animal pesticide across major phyla from protists, to molluscs, arthropods, and vertebrates. Arsenic has the potential to impact biological integrity, to adversely affect biodiversity and thus to negatively impact ecosystem health and function. Impacts to ecosystems occur in a number of ways, including atmospheric deposition to soils and aquatic ecosystems, direct application as pesticides to soil, accidental release from manufacturing facilities, absorption in aquatic ecosystems, plant uptake or animal ingestion from soil or sediment, and food web transfer.

Because arsenic is naturally occurring but has also been so widely used, particularly as a herbicide and pesticide in New Jersey, virtually all ecosystems have been exposed, with many plant and animal populations at risk. There are many sites in New Jersey with arsenic soil concentrations exceeding the recommended soil clean-up level of 20 mg/kg. Apparently, natural background levels in some parts of the State sometimes exceed 20 mg/kg, because of high arsenic containing minerals, such as glauconite. Since arsenical pesticide use was very extensive, particularly from the 1930's well into the 1960s, it may be difficult to distinguish natural from anthropogenically derived arsenic. Although instances of very high exposure may be limited to the vicinity of manufacturing or hazardous waste sites, the widespread application of arsenical pesticides has probably contaminated large areas of the State. Thus, although highly uncertain as to aerial extent, the Hazard quotient method, HQ = Env. Conc./Benchmark Conc. gives a rough indication of impact.

Statewide Analysis of Threat ***ARSENIC***

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	4	3	36

Marine Waters	2	3	1	6
Wetlands	3	4	3	36
Forests	2	2	1	4
Grasslands	2	2	1	4

Issue: Arsenic
Author: Tucker/Buchanan
Version: 05/09/00

Risk by Watershed Management Region

{tc \l1 "***ECOSYSTEM***}**Watershed Management Region**	ECOSYSTEM				
	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	M	NA	M	L	L
Passaic	M-H	L	M	L	L
Raritan	H	M	M-H	L	L
Atlantic	M	L	M	L	L
Lower Delaware	M	L	M-H	L	L
Region/Watershed (secondary)					
Urban	L	M	M	NA	NA
Suburban	M	L	M	L	L
Rural	H	L	M	L	L

H=high, M=medium, L=low, NA = not applicable

Issue: Arsenic
Author: Tucker/Buchanan
Version: 05/09/00

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor Description of stressor	**Asian Longhorned Beetle** (*Anoplophora glabripennis*) A non-native (exotic) insect pest of hardwood trees. The Asian longhorned beetle (picture on page 2) is large (about 1 inch long), shiny, and black with white spots (USDA, 1998a). It has very long horn-shaped antenna that are black with white rings; the elongated feet are black with a whitish-blue upper surface (USDA, 1998a). The beetle is native to China, Japan, Korea and the Isle of Hainan (Meyer, 1998). "The white, wormlike immature beetles bore into tree trunks and branches, causing sap to flow heavily from wounds. Large amounts of frass (sawdust and other insect waste) accumulate at tree bases. Adult beetles leave round holes in the bark that are a half inch across or larger. Unseasonal yellowing of leaves or dropping leaves when the weather has not been dry are other indicators that the pest may be present. If left unchecked, the beetles can spread and kill trees quickly once they enter an area." (USDA, 1998a) Asian longhorned beetles and other wood-boring pests are a serious threat to U.S. trees. These beetles bore deep into trees and eventually kill the tree through disruption of the nutrient/water systems (e.g., phloem and xylem vessels). There are no known treatments to combat the beetle, except destruction of infested trees. This beetle can feed on many types of hardwood species including maples (Norway, sugar, silver, and red), birch, pear, plum, horse chestnut, poplar, willow, elm, mulberry, and black locust. (USDA, 1998a, 1998b, 1998c) The life cycle of this beetle in China involves adult emergence between May and October, with the adults living about a month. During this time the adults live on the tree feeding on leaves, petioles and young bark. The female chews a slit into the trunk or branch and lay eggs (approximately 32 per female) under the bark. The larvae feed in the cambial layer of bark and later enter the woody tissues. The larvae pupate in a chamber in the heartwood; adults later emerge from a 10-millimeter hole. A generation develops in one to two years depending on climate and food. (Wong & Mong, 1986; Li & Wu, 1993 cited in EPPO, 2000) The Asian longhorned beetle and other wood-boring insects (e.g., *Hesperophanes, and Monochamus*) are considered quarantine pests by the Animal and Plant Health Inspection Service (APHIS) of USDA. APHIS has found numerous pests associated with solid wood packing material from China including those listed above (USDA, 1998c). Entry into the U.S. has been primarily in wood packing materials of imported goods.

In China, this beetle has damaged approximately 45% of the poplar plantations (Smith, 2000). The Asian longhorned beetle and another related species (*A. nobilis*) infested 568,000 acres in over 240 cities or counties; more than 50 million trees were cut down in one province from 1991 to 1993 (Smith, 2000).

Photo showing Asian longhorned beetle (*Anoplophora glabripennis*) egg (far left), larvae (left and bottom), pupa (middle), and adult (far right) (Source: USDA)

Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	This organism impacts ecosystems by feeding on trees resulting in tree damage and death. This wood-boring pest can impact terrestrial ecosystems by indiscriminant infestation and killing of hardwoods. Impacts could include reduction in biodiversity, reduced habitat/ecosystem health, and changes/loss in ecosystem function. Destruction of trees could reduce the abundance of native species and increase the abundance of exotic species (e.g., *Ailanthus altissima* (tree-of-heaven) and *Berberis thunbergii* (Japanese barberry). Extensive forest loss can result in changes in forest dynamics/functions (e.g., reductions in wildlife habitat, alterations to the water and nutrient cycles) and have secondary effects (e.g., increased erosion, increased stream temperatures due to canopy loss).
Key impacts selected (critical ecological effects)	The qualitative assessment considered reduction in biodiversity, reduced habitat/ecosystem health, and changes/loss in ecosystem function.
Exposure Assessment	
Exposure routes and pathways considered	The primary exposure route is introduction of the pest at U.S. ports of entry (e.g., New York/New Jersey Harbor) in solid wood packing material. The volume of solid wood packing material has increased tremendously, as the volume of Chinese imports has increased from $5 billion in 1985 to $72.8 billion in 1997 (Meyer, 1998). Once introduced the insects (i.e., eggs, larvae, and pupae) can be spread by movement of infested wood (e.g., firewood, untreated lumber) or by the adult beetles flying to nearby trees. Adult beetles are weak flyers capable of flying up to 1200 meters (m) (USDA, 1998c). Infestations in China were found to spread slowly, less than 300 m per year in Beijing poplar groves (Their, 1997 cited in USDA, 1998c). Larvae can feed on 47 tree species in China, including 23 species of poplar (Yang et. al., 1995 cited in USDA, 1998c).

Population(s)/ecosystem(s) exposed statewide	Ecosystems containing hardwoods would be primarily at risk to exposure from introduction of this pest. This would include forest ecosystems and wetlands (e.g., forested wetlands). Other ecosystems which include hardwood trees (i.e., urban and recreational) would also be at risk to exposure.
Quantification of exposure levels statewide	Currently there is no known exposure of NJ's ecosystems to this insect pest. The beetle has been discovered in several NJ warehouses, but has not been found outside the buildings. The beetle has infested several areas in New York City; due to the proximity of the infested areas to NJ, the State is at risk of exposure. Although tree surveys for the beetle have been conducted in NJ with no detections, APHIS estimates that inspectors identify only about one-third of beetle infested trees when using binoculars from the ground (Becker, 2000). Therefore, it is possible that this insect has been introduced into New Jersey. As of August 6, 1998, beetles have been found in warehouses at 26 locations in 14 States across the country. In New Jersey the beetles have been found in warehouses in Cream Ridge, Linden, and New Brunswick. There have been infestations found outside of warehouses in Chicago, Du Page County, and Summit, IL; and Amityville and Brooklyn, New York. APHIS has placed the infested areas under official control through quarantines and eradication programs. The breeding populations in New York and Illinois have been reduced but not eradicated. If introduced into NJ's ecosystems, potentially all of the State's hardwood forests are at risk. There are approximately 1,991,000 acres of forested land in the State (USDAFS, 2000), although not all of this is hardwoods.
	This species appears to infest maple trees in the U.S. to a greater degree than other species. Maples comprise approximately 30% of all urban trees in the eastern U.S. (Smith, 2000), and 35% of New Jersey's street trees are maples (NJDEP, 2000).
Specific population(s) at increased risk	Hardwood forests and urban parks. Two well-known urban parks (New York City's Central Park and Chicago's Lincoln Park) are presently at risk due to their proximity to infested trees/areas. Urban parks in NJ may be at increased risk due to their proximity to areas with buildings/warehouses that handle imported goods.
Quantification of exposure levels to population(s) at increased risk	No quantification is possible at this time since there have been no reports of exposure to NJ's ecosystems. Potentially large areas of NJ's hardwoods are at risk if the Asian longhorned beetle becomes established in the State.
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	No quantitation of risk was employed. A qualitative assessment was used based on a USDA (1998c) risk assessment of the Asian longhorned beetle and other literature sources.
Risk Characterization	USDA (1998c) conducted a risk assessment for the Asian longhorned beetle. The following is a summary of the overall rating of pest risk potential:

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	Factor / **Rating** Likelihood of Entry — High Likelihood of Establishment — High Consequences of Introduction — High Pest Risk Potential — High	
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		**Score**
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery	Current assessment is rated a "1" due to no detectable exposure to ecosystems as of December 2000. Potential rating, assuming infestation occurs would be a "4" due to the widespread damage to hardwoods that this insect can cause and associated impacts to the ecosystems (i.e., forest, urban). Secondary impacts (e.g., forest loss leading to increased erosion) could potentially impact other ecosystems (i.e., inland waters). However, these impacts would probably be less severe (rating of "3", see Statewide Table).	Current =1 Potential = 4
3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduc Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	The USDA (1998c) rated the impacts of introduction and establishment of the Asian longhorned beetle as high. They also state that this pest could have devastating impact on our forests and agriculture. USDA (1998c) mentions reports of severe damage to forests in China. Members of the Biological Control Institute of the Chinese Academy of Agricultural Sciences consider this beetle to be one of the most serious forest pests in China.	

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Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Currently infestation with the Asian longhorned beetle is rated a "1", possible in the future, due to the absence of infestations in ecosystems of the State. The beetle has been found in warehouses in 3 cities in NJ, but no reports of infestations outside the warehouses. Potential frequency is rated much higher. If the insect gets established, frequency of effects could become a "4", often and continuing. The USDA (1998c) rates this insect as having a high potential for entry.	Current =1 Potential =4
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	The Asian longhorned beetle occurs in temperate climates in China (USDA, 1998c). This indicates that conditions are favorable for establishment in New Jersey. Currently none of the State has been affected by this insect, and extent of the State affected is rated a "1". However, if the beetle is introduced to the State and control efforts fail, the magnitude of effect could include much of the State and is rated a "4" (potential future effects).	Current = 1 Potential = 4
	Total	Current = 1 Potential = 64
Assessment of uncertainties in this assessment (H,M,L) and brief description	M – uncertainties include the possibility that this pest has been introduced into NJ's ecosystems but not yet detected; impacts on forest ecosystems have not been well-studied or sufficiently reported thereby leading to uncertainty with the magnitude of impacts; the efficiency of eradication efforts (e.g., in New York) has not been fully determined.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	H – continued/increased monitoring for this organism in New Jersey could determine if the insect has been introduced. Additional study/reporting on the adverse impacts on forest ecosystems is needed to determine the magnitude of effects.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, ! , =, ≡; where + is improvement), and brief description.	+ - new biological and other controls are being studied. The impacts of this beetle can be reduced if a successful technique/organism can be found. Natural enemies of this beetle have been described in China including the cylindrical bark beetle, woodpeckers, and pathogens (Smith, 2000). A systemic insecticide has also been recently tested which may prove effective against this pest. Imidacloprid (e.g., Merit or Imicide) has been tested by USDA and Chinese researchers and shown to cause adult, as well as some egg and early instar larvae mortality (Nixon, 2000). Improvement in risk may occur if the 1998 changes in regulations concerning treatment of solid wood packing material from China are effective.	
Potential for catastrophic impacts* (H,M,L) and brief description	Low to Moderate: low rating due to lack of current infestation in the state; moderate rating since serious damage could occur to the State's forests if the beetle is introduced; the absence of natural predators and the need for severe controls (i.e., destruction of infested trees) could result in widespread damage.	

(*Short-term drastic negative impacts having widespread geographic scope)	
Link to other Work Groups (e.g., socioeconomic impacts)	Control efforts in the U.S. have cost approximately $5 million since 1996 and resulted in the destruction of more than 2,000 trees. In China the Asian longhorned beetle has been reported to seriously reduce poplar fiber and wood production; it can also affect agricultural crops indirectly by killing trees used as windbreaks around crop fields (USDA, 1998c). USDA concluded that data from China suggests this beetle would "severely impact U.S. forest resources and related industries, such as timber, nursery, tourist, and maple syrup." USDA predicted that if the beetle is introduced to North American forests, annul losses to the U.S. economy would be approximately $138 billion. Aesthetics and costs of tree destruction in urban (e.g., NY) and suburban areas should also be considered.
Extent to which threat is currently regulated or otherwise managed	APHIS has issued pest alerts to port-of-entry personnel, conducted outreach to importers, targeted high-risk importers and Chinese exporters for outreach and increased inspections, conducts inspections at warehouses, and conducts periodic blitzes at ports of entry to inspect targeted Chinese shipments with solid wood packing materials (USDA, 1998b). In 1998, U.S. entry requirements (7CFR 319.40) were changed. All solid wood packing materials exported from China and Hong Kong must be treated before entering the U.S. to reduce the risk of introducing dangerous pests such s the Asian longhorned beetle (USDA, 1998c). Treatments include methyl bromide fumigation, phosphine fumigation, use of preservatives (e.g., arsenic, copper, creosote, chlorpyrifos), or use of kiln dried wood. The NJ Department of Agriculture's Division of Plant Industry has responsibility and statutory authority for the control of infectious or contagious diseases of plants and injurious insects and other plant pests. Included in this responsibility is the inspection of nursery stock that is offered for sale in the state or for shipment out of the state to ensure freedom from plant pests. The Pest Detection program is designed to detect new plant pests not previously known to occur in NJ, including Asian longhorned beetle and many other insects and other arthropods, weeds, and pathogens (Balaam, 2000). The NJ Forest Service also has an Insect & Disease Management program.
Barriers to restoration	Difficulty with exterminating this organism once introduced, and lack of non-destructive controls will be a barrier to restoring infested trees and forests.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	H – importers/exporters of goods from China and Hong Kong are the primary source of this pest, most of which arrives via ship transportation.
Small business industry	H – importers/exporters of goods from China and Hong Kong are the primary source of this pest, most of which arrives via ship transportation.
Transportation	H – importers/exporters of goods from China and Hong Kong are the primary source of this pest, most of which arrives via ship transportation.
Residential	L
Agriculture	L

Recreation	L
Resource extraction	L
Government	L
Natural sources/processes	L
Orphan contaminated sites	L
Diffuse Sources	
Sediment sinks	L
Soil sinks	L
Non-local air sources incl. Deposition	L
Biota sinks	H – once introduced, this insect can infest other areas through reproduction and migration.

Summary Statement: The Asian longhorned beetle is a non-native (exotic) insect pest of hardwood trees introduced to the United States from China, primarily in solid wood packing material associated with imported goods. Immature beetles bore into tree trunks and branches to feed and result in tree damage and death. If not eradicated, the beetles can spread and kill trees quickly. There are no known treatments to combat the beetle, except destruction of infested trees. This beetle can feed on many types of hardwood species including many species found in New Jersey.

Ecosystems containing hardwoods would be primarily at risk to exposure from introduction of this pest. This would include forest ecosystems and wetlands (e.g., forested wetlands). Other ecosystems which include hardwood trees (i.e., urban and recreational) would also be at risk to exposure. Secondary impacts to inland waters could occur if forest damage is severe (i.e., increased erosion).

Currently there is no known exposure of NJ's ecosystems to this insect pest. The beetle has been discovered in several NJ warehouses, but has not been found outside the buildings. The beetle has infested several areas in New York City; due to the proximity of the infested areas to NJ, the State is at risk of exposure.

The USDA has rated the risk of this species to the U.S. as **high** using the following four factors: 1) likelihood of entry, 2) likelihood of establishment, 3) consequences of introduction, and 4) pest risk potential. The risk to NJ's ecosystems, based on current impacts, was rated "low" due to the absence of observed infestations and impacts in New Jersey. Potential risk of impacts of this beetle are rated "high" if the insect becomes established in the State.

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Statewide Analysis of Threat   Threat = Invasive Animals: Asian Longhorned Beetle

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	1 (3)	1 (2)	1 (2)	1 (12)
Marine Waters	NA	NA	NA	NA

Wetlands	1 (4)	1 (4)	1 (2)	1 (32)
Forests	1 (4)	1 (4)	1 (4)	1 (64)
Grasslands	1 (1)	1 (1)	1 (1)	1 (1)
			Total Score	4 (109)
			Average Score (Total ÷ 5)	<1 (21.8)

Note: number in column is current risk; number in parenthesis is potential risk if introduced

Risk by Watershed Management Region

THREAT = Asian Longhorned Beetle	**ECOSYSTEM** Note: letter in column is current risk; letter in parenthesis is potential risk if introduced				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L (L)	NA	L (M)	L (H)	L (L)
Passaic	L (M)	NA	L (M)	L (H)	L (L)
Raritan	L (M)	NA	L (M)	L (H)	L (L)
Atlantic	L (L)	NA	L (L)	L (H)	L (L)
Lower Delaware	L (L)	NA	L (L)	L (H)	L (L)
Region/Watershed (secondary)					
Urban	L (M)	NA	L (M)	L (H)	L (L)
Suburban	L (L)	NA	L (M)	L (H)	L (L)
Rural	L (L)	NA	L (M)	L (H)	L (L)

H=high, M=medium, L=low, NA = not applicable.

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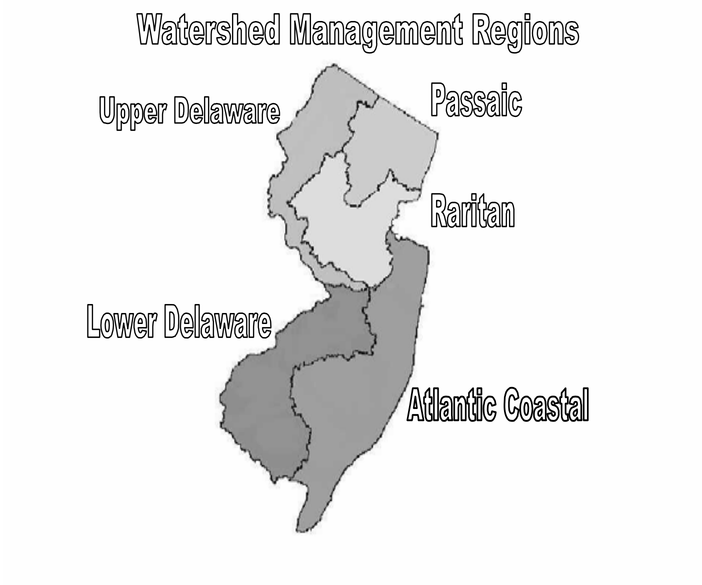

Issue: Blue-Green Algae
Author: M. Gastrich
Version: 08/16/00

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Stressor:
Blue-Green Algae in Water Supplies

Issue: Toxic algal blooms in freshwater lakes, reservoirs and potable water systems are well controlled by algicides but there is a potential the release of the toxin after algaecide treatment. Treatment with alum and lime has been found to reduce the release of toxins as opposed to the use of legally registered algicides.

Severity Code: LOW
With management = 1 in terms of bloom control
Without management = 2 in terms of bloom control

Confidence/Uncertainty: High confidence in terms of the algal bloom control but some uncertainty in terms of potential effects of putative release of the toxin, microcystin, in the event of rapid lysing of *Microcystis* blooms using legally registered algicides.

Trend: (0) Same, no expected increase in the incidence of toxic algal blooms.

Catastrophic Potential: Low

Eutrophication is common in lakes, which may be due to the high loadings of nutrients (e.g., phosphorus). *Eutrophication is the process of becoming rich in nutrients and can be a natural sequence in lakes/ponds over geological ages (Atlas & Bartha 1981). This process can be hastened by anthropogenic activity (e.g., nutrient enrichment) causes dramatic changes in lake character within years or decades instead of geological ages (Atlas & Bartha, 1981).* Phytoplankton, such as cyanobacteria thrive in eutrophic waters and decrease the economic value of recreational lakes (Lam et al. 1995). Cyanobacteria have bacterial cell structure and are photosynthetic (similar to plants, they can produce sugars, from sunlight, chlorophyll and water, and produce oxygen), previously classified as "blue-green algae". Cyanobacteria toxins are naturally produced toxins produced by various cyanobacteria.

The neurotoxins and hepatotoxins associated with cyanobacterial blooms are responsible for deaths in wild and domesticated animal populations and have various acute and chronic pathogenic effects on humans (Neilan, 1995). Some species of cyanobacteria produce two types of intracellular toxins: alkaloid neurotoxins (*Anabaena* spp and *Aphanizomenon* spp) attack the nervous system and cyclic hepatotoxins (*Microcystis spp., Anabaena spp.* and *Oscillatoria spp*.) attack the liver (Lam et al. 1995; Carmichael et al., 1985). In freshwater, anatoxin-*a* is the most commonly reported neurotoxin and microcystin-LR is the most commonly reported hepatotoxin.

The colonial species, *Microcystis aeruginosa,* is the most common toxic cyanobacteria found in eutrophic freshwater and it produces hepatotoxic cyclic heptapeptides, termed "microcystins", that have molecular weights ranging from 952 to 1067 daltons (Vasconcelos et al, 1993). The major route of human exposure to microcystins is drinking water (Health Canada, 1998). Reports of human illness are also linked to the recreational uses of water which has been contaminated by blooms such as *Anabaena* and *Microcystis* in North America, the United Kingdom, the Netherlands and Australia (Health Canada, 1998). In these cases, the exposure was through skin contact and some ingestion of water containing the microorganisms (Health Canada, 1998).

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In the U.S. and Australia, several cyanobacteria toxins have been implicated in human illness (e.g., possible liver damage) that was associated with algal blooms in specific municipal water supplies treated with an algicide containing copper sulfate (reported in Health Canada, 1998; Bourke et al. 1983; Falconer, 1989; Ressom et al, 1994). There is strong evidence that cyanobacterial blooms were present at the water intake area or in open reservoirs (Health Canada, 1998). Also, mortalities in animals have been reported after consuming water containing large numbers ($>10^6$/mL) of cyanobacteria cells (Carmichael, 1992). Animal studies have been conducted on the relationship of cyanobacteria toxins to short-term and long-term toxicity, reproductive and developmental toxicity in embryos, and tumor promotion (Health Canada, 1998).

Because some of the bloom-forming cyanobacteria produce highly toxic secondary metabolites, they were responsible for poisoning and death of livestock and wildlife in Alberta, CA after the ingestion of water or toxin-containing cells (Baddaloo et al., 1993). These compounds have been implicated in poisonings of domestic livestock, pets and wildlife after the animals consume toxin-containing water and/or cyanobacteria cells from lakes, ponds, and farm dugouts (Lam et al., 1995; Beasley et al., 1983; Elder et al., 1985; Soll and Williams 1985; Galey et al, 1986).

More than a century has passed since the first recorded incident of mass mortality of domestic cattle associated with cyanobacteria poisoning (Baddaloo et al., 1993). Since then, many intermittent but repeated cases of these type of poisonings have occurred world-wide involving livestock, pets, and wildlife. Death occurs quickly after ingestion of only a few mL of water and cells if the bloom material contains sufficient toxin (Baddaloo et al, 1993). There are some reports of the intoxication of fish in eutrophic reservoirs of south Portugal, but no direct correlation was established between fish mortality and cyanobacteria toxins in the water (Vasconcelos, 1993).

Cyanobacteria can also cause massive die-offs of sport fish, and produce green and blue-green paint-like slicks or scums along shorelines, thus decreasing the recreational value of a lake. They can also severely impair water quality by producing pungent odors and tastes that give drinking water an earthy or musty character (Kotak et al., 1995).

The NJDEP's Bureau of Freshwater and Biological Monitoring reported the occurrence of *Microcystis* sp. in various lakes in NJ (Bud Cann, pers. comm.). An apparent bloom of blue-green algae was severe enough to interfere with the treatment process at the Passaic Valley Water Commission. The NJDEP conducted an algal bloom study in this area and found three species to be dominant: *Microcystis aeruginosa* (most abundant), *Anabaena circinalis and Aphanizomenon flos-aqua* (NJDEP, 1996). Cyanobacteria can cause filter clogging at potable intakes on the Pompton/Passaic (Olsen and Kurtz, 1995).

While freshwater algal blooms can be controlled with algicides, which are commonly used in water treatment and in application in lakes and reservoirs, there is a ancillary issue that may need to be evaluated in the future with respect to algal treatment. A study has shown that most microcystin-LR toxin remains in the *Microcystis* until the cell is lysed (= broken open after death) (Lam et al. 1995). A sudden release of microcystin into the ambient water can present a significant health hazard to livestock and humans using the water for consumption (Lam et al. 1995). However, the persistence of microcystins is not well-documented (Lam et al. 1995). It has been shown that lime or alum treatment is more favorable than algicides and chlorine for the control of floating toxic algal blooms of cyanobacteria because they appear to control the bloom by cell-coagulation and sedimentation (versus lysis and release of toxins) leaving a clear water phase (Lam et al. 1995). However, neither material is legally registered by the USEPA or the NJDEP for use an algicide. The use of the pesticide diquat (which is registered for use for filamentous algae control) resulted in significant release of cyanobacteria toxins in to the water phase and was not recommended for use in controlling these algal blooms (Lam et al. 1995). Sudden increases of nutrients, such as phosphorus and ammonium after diquat treatments often resulted in secondary blooms (Lam et al. 1995). The use of alum and lime were observed to reduce algal bloom density in the second year in drinking water reservoirs (Lam et al. 1995).

The NJDEP 's Bureau of Pesticide Operations, as part of the Pesticide Control Program, issues over 800 permits a year in the state for the use of pesticides on aquatic sites, including the use of algicides in ponds, lakes and reservoirs. Most of these algicides contain copper sulfate or copper derivatives, which are toxic to algae and cause algal die-offs. The Bureau reported one possible human health effect due to cyanobacteria toxins in New Jersey in 1999. A child experienced a rash and diarrhea after swimming in a 10 acre lake that had the swimming area treated with copper sulfate. The child was referred to his family doctor, who attributed the symptoms to cyanobacteria toxins (Ralph Smith, pers. comm.). Therefore, evaluations of the presence of microcystin in the drinking water and/or areas designated for swimming, associated with the treatment of or rapid die-off of algal blooms, may be an area for further study.

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor Description of stressor	**Brown Tide Blooms** ***Aureococcus anophagefferens*** Single-celled, eukaryotic, minute (< 2-4 μm) pelogophycean (=golden brown algae) alga (both autotrophic and heterotrophic); blooms cause attenuation of light and cause the water to discolor golden-brown; restricted to shallow, relatively unstratified estuaries; no evidence of blooms in open ocean; regional occurrence of organism in estuaries from the Gulf of Maine to Great Bay, NJ; extensive destructive blooms in 1985 in Long Island bays, Narragansett Bay and possibly, Barnegat Bay, NJ . *A. anophagefferens* was confirmed as associated with the brown tide bloom in Barnegat Bay and Little Egg Harbor in 1995 (Nuzzi et al. 1996). There were reports of a bloom in 1997 and also reports of a significant bloom in 1999 but data on cell counts for those years are not available. Potential Causative Factors Promoting Blooms In general , there are many ongoing studies of brown tide blooms but at this point, there do not appear to be any conclusive data to support cause and effect link. However, brown tide bloom onset is associated with reduced estuarine flushing rates and elevated salinities in Long Island bays (Cosper et al. 1989; Keller and Rice 1989; Anderson et al. 1993) and meteorological forcing (e.g., reduced wind stress and low subtidal sea level oscillations (Vieira 1989; Vieira and Chant 1993). Brown tide blooms in Long Island bays followed unusual winter and spring drought periods (Cosper et al. 1987); optimum temperature for growth in cultures ranges between 20 and 25 ^{0} C for cultures acclimated at 20 ^{0} C (Cosper et al. 1989). Temperatures in late Spring appear to promote blooms. *A. anophagefferens* has the ability to maintain high growth efficiency under "nutrient-saturating" conditions, up to 10 ^{6} cells per mL (Milligan 1992) when compared with other algae. The brown tide organism can grow at very low levels of dissolved organic nitrogen (DON)– known to limit other phytoplankters including diatoms (Keller and Rice 1989). Micronutrients appear to be important to onset of blooms (Fe, Se)(Cosper et al. 1993 and others). Several studies of brown tide bloom factors in Long Island bays strongly suggest that Aureococcus blooms do not occur in response to eutrophication (inorganic macronutrient loading)(as summarized in Bricelj & Lonsdale, (1997). A general view is that the 1985 brown tide blooms in Long Island bays were partly regulated by salinity (Cosper et al. 1987; Cosper et al., 1989; Sieburth et al., 1988). As part of the "rainfall hypothesis", at least three factors in a potential link between the initiation of the brown tide bloom and salinity include: an osmotic effect; growth rate dependency; and a flushing rate effect (for which salinity serves as a marker (Smayda & Villareal, 1989). Low rainfall levels, lowered sea level and expected reduction in the flushing rates in Long Island bays where brown tide bloomed have been noted (Cosper et. al. 1987).
	Recently, several hypothesis have been developed known as "bottom up" if they explain factors which promote blooms and "top down" for factors which eliminate blooms. Recent studies have shown that some algal species (e.g.,

	Aureococcus anophagefferens) are not significantly correlated to inorganic nutrients but may be more associated with organic nutrients (Gobler and Sanudo-Wilhelmy, 2001). In fact, high levels of DIN suppressed the growth of *A. anophagefferens* (Keller and Rice; 1989; Nixon et al., 1994). Based on long-term data and nitrogen budgets, it is hypothesized that in Long Island coastal bays, there is an inverse correlation between groundwater flow, with a subsequent supply of DIN, and *A. anophagefferens* cell densities (LaRoche et al, 1997). In years with low ground water flow, shifts in the DIN:DON ratio provide an increased DON supply which is a factor in controlling brown tide blooms (LaRoche et al, 1997). The initiation of the brown tide blooms in Long Island bays may be controlled by the ratio between the inorganic nitrogen supply (DIN), favoring normal phytoplankton and macroalgae species, and the organic species (DON) favoring brown tides (LaRoche et al., 1997). The lack of rainfall and effects on the relative availability of inorganic (DIN) and organic nitrogen (DON) may have predicted brown tides in Peconic Bay, NY but not in adjacent coastal bays (Berg et al., 1997; Gobler and Sanudo-Wilhelmy, 2001; Lomas et al., in press). Brown tide blooms in Long Island (NY) and Maryland coastal bays in 1999 were associated with ratios of organic nutrients such as greater than Redfield DOC:DON ratios and DON:DOP ratios (Lomas et al., in press). Moreover, another recent study in the tributaries of the Chesapeake and coastal bays of Maryland showed that all bloom periods, over a three years of blooms (1997-1999), of *Pfiesteria piscicida, Aureococcus anophagefferens,* and *Prorocentrum minimum,* occurred with elevated ratios of dissolved organic carbon (DOC) to DON as compared to non-bloom periods (Glibert et al. in press). However, there is no similar pattern of elevated N:P ratios during bloom versus non-bloom periods (Glibert et al. in press). Recent Results of Ongoing Studies (Brown Tide Research Institute)(BTRI). Results of recent ongoing studies into causative factors of blooms include the following findings: Results of experiments during the West Neck Bay, NY brown tide bloom, it appeared that dissolved organic nitrogen is not required for bloom initiation, but rather may contribute to sustaining a bloom (Sanudo-Wilhelmy, Hutchins, Donat and Gobler, 1998).
	Results of mesocosm studies in Long Island bays have lead to a bay-wide working hypothesis that interations among the pelagic microalgal consumers may play a central role in determining the success of *Aureococcus* in planktonic communities (Caron & Lonsdale, BTRI, 1999). Results of field experiments in Long Island's embayments, brown tide's growth was increased by additions of dissolved organic carbon (DON) (Snudo-Wilhelmy, Hutchins & Donat, BTRI, 1999); seepage rates can play a significant role in altering the chemical flux of nutrients, organics, and trace metals (Al, Cu, Mg, Cd, Fe, and Ag) to groundwater entering the bay and can impact bay productivity When various numbers of hard clams are present in mesocosms, *Aureococcus* growth rates are significantly reduced – the presence of high numbers of filter feeding bivalves may act to limit brown tide bloom formation (Caron & Lonsdale, BTRI, 1999).

	Studies are ongoing to understand the dynamics of the 1985 bloom in Narragansett Bay including a special focus on flushing, wind intensity, groundwater, nutrients, temperature and other environmental variables (Smayda, BTRI, 1998). Status of Brown Tide Blooms in NJ Recurring brown tide blooms have been documented in 1995, 1997, and 1999. Because of limited available data on these blooms, the NJDEP's Division of Science, Research & Technology established the Brown Tide Assessment Project to conduct monitoring in 2000. The objectives of the project were to: characterize the spatial and temporal distribution of brown tide blooms in coastal bays and quantify the presence of viral-like particles in natural populations of *A. anophagefferens*. 2000 Results (Gastrich, 2000-01) No blooms occurred in Raritan Bay, northern Barnegat Bay, open ocean sites, or in coastal bays between Great Bay and Great Egg Harbor. Full or significant blooms (>10^6 cells mL^{-1}) occurred only in Little Egg Harbor during June. Smaller blooms (>10^5 cells mL^{-1} and <10^6 cells mL^{-1}) occurred in Little Egg Harbor and in some stations to the north in southern Barnegat Bay, to the south in Great Bay Inlet in June, July, August and at one station in Great Egg Harbor. The highest concentrations of *A. anophagefferens* were at station 1820A (Tuckerton Bay in Little Egg Harbor) at $2.2 \cdot 10^6$ cells mL^{-1}. Other stations with over 2 million cells mL^{-1} occurred at stations 1818D at Tuckerton, NJ and at station 1719E near North Beach Haven on the eastern side of the Little Egg Harbor).
	For the first time, smaller blooms were confirmed in areas farther south than Little Egg Harbor. The two open ocean sites had concentrations less than 10,000 cells mL^{-1} to the tens of thousands. 2001 Results (Gastrich, 2001; Gastrich et al., 2001; Gastrich & Wazniak, 2001) 2001 monitoring had fewer stations but ranged from Raritan Bay south to Great Egg Harbor Bay. Brown Tide Bloom Index (Gastrich & Wazniak, 2001) was developed to assess monitoring results. The Index relates brown tide concentrations to potential impacts and characterizes blooms in three categories. For a copy, contact Dr. Mary Downes Gastrich, Brown Tide Assessment Project Manager, at (609) 292-1895. The most severe blooms, Category 3 blooms (>200,000 brown tide cells per milliliter, cpm) occurred in 2000 and 2001 in southern Barnegat Bay, Little Egg Harbor and Great Bay - concentrations can be significantly harmful to shellfish, eelgrasses, and other natural resources.

	Category 2 (less severe : >35,000 to <200,000 cpm at blooms occurred in one Raritan Bay station in 2000 and in northern Barnegat Bay, Little Egg Harbor, Great Bay and Great Egg Harbor Bay stations in 2000-01- concentrations that can be potentially harmful to juvenile shellfish Category 1 (< 35,000 cpm with no observed impacts) blooms were observed in some coastal bays south of Great Bay in Spring months. There are reports that hard clam aquaculture facilities have observed a reduction in growth of juvenile hard clams every year during brown tide blooms in Tuckerton Bay The most important result of two years of monitoring was that Category 2 blooms, that have been shown to damage shellfish, occurred in 2000 and 2001 in coastal bays from Raritan Bay south through Barnegat Bay, Little Egg Harbor, Great Bay, and Great South Bay. **NYS Brown Tide Research Initiative (BTRI)** Scientists funded to conduct studies on Aureococcus include: Bigelow Laboratory for Ocean Sciences, ME (Robert Andersen, Maureen Keller, Michael Sieracki) University of Southern California and Woods Hole Oceanographic Institution , MA (David Caron) Graduate School of Oceanography, RI (Theodore Smayda) Northeast Fisheries Science Center, CT (Richard Robohm, Gary Wikfors) Marine Sciences Research Center, NY (SUNY)(Darcy lonsdale, Sergio Sanudo-Wilhelmy) Brookhaven National Laboratory, NY (Julie La Roche) SUNY college of Environmental Science and Forestry, NY (Gregory Boyer) College of Marine Studies, DE (David Hutchins) Horn Point Environmental Laboratories, MD (Patricia Glibert, Todd Kana) Old Dominion University, VA (John Dona) Lamont Doherty Earth Observatory of Columbia University (Mary Downes Gastrich) (brown tide viral research)
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	**Biological integrity, biodiversity, habitat/ecosystem health, and ecosystem function** **A. Benthic impacts**: **(hard clams, bivalves, eelgrass)** Blooms in Barnegat Bay's Little Egg Harbor are associated with reduced growth of juvenile **hard clams**, *Mercenaria mercenaria,* growth (Nuzzi et al. 1996); Biosphere, Inc, (Tuckerton, NJ); Brown tides caused devastation of vulnerable shellfisheries including: Long Island south shore bays (mid-1980s), including adverse effects on adult and larval stages of suspension-feeding **bivalves** and caused the mass mortalities of bivalves including the demise of bivalve mollusk populations (e.g., bay scallops, *Argopecten irradians)* (Bricelj et al. 1987; Bricelj & Lonsdale, 1997).. In Narragansett Bay, RI, in 1985, the brown tide blooms caused mortalities to the mussel, *Mytilus edulis* (Tracey*,* 1988).

	Blooms coincide with the growth season of **eelgrass**, *Zostera marina,* in Long Island bays. The blooms caused severe light attenuation due to high density and enhanced light-scattering properties of minute algal cells, that lead to a reduction in eelgrass coverage (Dennison et al. 1980); eelgrass beds provide nursery habitat for finfish and shellfish and loss of eelgrass beds in Long Island bays may have contributed to poor recruitment of juvenile bay scallops (Pohle et al. 1991; Tettlebach and Wenczel 1993); Loss of eelgrass beds in Long Island bays from brown tide blooms were implicated in **poor recruitment of juvenile bay scallops** (Tettelbach and Wenczel, 1993); extended algal blooms (= 2 months or longer) result in severe shading on growing eelgrass beds (McLain & McHale 1996; Dennison et al., 1989). Adult bay scallops suffered severe reduction in adductor muscle weight (Bricelj et al. 1989) in Peconic Bays; During the reported 1999 brown tide bloom in Little Egg Harbor, NJ, there were reports that ducks were not present during the brown tide event – most likely due to the fact that ducks could not see their food as a result of the dense bloom and were temporarily feeding elsewhere; Biological integrity, biodiversity (cont.) B. Planktonic effects (bivalve larvae, protozoa) Brown tide blooms coincide with spawning, planktonic **larval** development and juvenile growth of important **bivalves** in mid-Atlantic estuaries (e.g. mussels, scallops), Brow n tides have adverse effects on both adult and larval stages of suspension-feeding vivalves and they are implicated as the direct cause of the demise of vivalvemollusc populations in Narragansett Bay (Tracey 1988). *A. anophagefferens* causes significant growth reduction and high mortalities of **bay scallops** (*A. irradians)* **larvae,** even when present in a mixed suspension with good algal food sources (Gallagher et al. 1989); Detrimental effects to **protozoa** (aloricate ciliates but not tintinnids) were found at <u>higher densities</u> of brown tide (>5X10^{6} cells per ml $^{-1}$) in West Neck Bay in 1991 (LI, NY) (summarized in Lonsdale et al. 1996). And negative impacts on ciliates were found again in 1995 (Mehran 1996). A prolonged brown tide blooms is expected to have widespread detrimental effects on production rates of higher trophic levels because of its impacts on protozooplankton (Brijeli & Lonsdale, 1997). Feeding rates of some bivalves are suppressed at moderate to high concentrations of toxic *Aureococcus* strains but were maintained at cell densities below about 20,000 cell per mL. (Bricelj, BTRI 1999). Short term growth experiments on hard clams showed that *Aureococcus* densities of only 35,000 per mL were sufficient to cause harmful effects such as inhibition of clam feeding (Bricelj, BTRI 1999). Long-term growth experiments on hard clams and mussels showed that the 1995 brown tide isolate from LI bays, mixed with nutritious algae was highly toxic to both bivalve species at high (10^{6} cells per mL0 and moderate (4.0 X 10^{5} cells per mL) concentrations.
Key impacts selected (critical ecological effects)	Key impacts of brown tide in NJ include reduction in growth of juvenile hard clams. There are other key impacts (e.g., mortalities to shellfish and reductions in eelgrasses during dense prolonged blooms) that need to be better characterized; no data on other impacts; public concern for the (temporary) relocation of birds to another feeding source (without brown tide) may be a concern
Exposure Assessment	
Exposure routes and pathways considered	For key impacts, there are data on reductions in growth to juvenile hard clams and no data on other impacts.

Population(s)/ecosystem(s) exposed statewide	**Marine/estuarine aquatic Ecosystems**: Barnegat Bay and Little Egg Harbor extending to Great Bay and potentially, many other similar shallow estuaries having elevated salinities (>27-28 ppt), reduced flushing times, and other environmental factors. **Populations:** shellfish beds with brown tide duration of greater than one month; eelgrass beds.
Quantification of exposure levels statewide	**Spatial:** Brown tide blooms were suspected in NJ as far back as the mid-1980s in Barnegat Bay and Little Egg Harbor. Confirmation of *A. anophagefferens* blooms was not until the mid-1990s using a polyclonal antibody method for enumeration. However, other shallow estuaries in NJ having relatively similar characteristics and environmental variables may be affected in the future. Barnegat Bay is approximately 48,000 acres with a drainage area of approximately 352,000 acres. Brown tide blooms could potentially affect other estuaries. The total estuarine wetlands in NJ include about 289,505 acres of wetlands (which are 31.5% of all NJ wetlands, Tiner, 1985). **Temporal:** Brown tide blooms or brown discolored water in New Jersey is observed typically beginning in May and continuing through June and subsiding in July. Depending on various environmental factors, a second bloom in early fall has also been observed in Barnegat Bay (Mahoney, pers. comm.). The brown tide organism has been observed in waters throughout the year (Mahoney, pers. comm.) but data on brown tide counts have not been available. Long Island's South Shore bays have experienced elevated numbers of brown tide counts in the winter months (Suffolk Co., 1999). Beginning in 2000, the NJDEP conducted sampling and enumeration as part of its Brown Tide Assessment Project.
Specific population(s) at increased risk	**In Barnegat Bay and Little Egg Harbor, NJ**: **Benthic populations**: eelgrass beds, mussels and hard clams at aquaculture facilities in Tuckerton (hard clams) and in other areas in Great Bay; **Planktonic populations** (e.g. protozoa, copepods, larval stages of shellfish); potentially at risk.
Quantification of exposure levels to population(s) at increased risk	Exposure to brown tide blooms currently occur only in waters in the southern part of Barnegat Bay and Little Egg Harbor during months of May to July and again, a second bloom is possible in September/October; blooms potentially could occur in any shallow estuary with similar characteristics and/or environmental variables.
Dose/Impact-Response Assessment	

Quantitative impact-assessment employed	Unusually high mortalities (up to 64-80%) of adult bay scallops in Long Island bays with concomitant brown tide blooms, measured from the incidence of articulated "clucker" shells, were determined immediately after the 1995 brown tide in Peconic Bay sites where A. anophagefferens densities reached 0.8 – 1.1 X 10^6 cells ml $^{-1}$ (C. Smith pers. comm.; reported in Bricelj & Lonsdale, 1997); Feeding rates of some bivalves are suppressed at moderate to high concentrations of toxic *Aureococcus* strains but were maintained at cell densities below about 20,000 cell per mL. (Bricelj, BTRI 1999). Short term growth experiments on hard clams showed that *Aureococcus* densities of only 35,000 per mL were sufficient to cause harmful effects such as inhibition of clam feeding (Bricelj, BTRI 1999). Long-term growth experiments on hard clams and mussels showed that the 1995 brown tide isolate from LI bays, mixed with nutritious algae was highly toxic to both bivalve species at high (10^6 cells per mL0 and moderate (4.0 X 10^5 cells per mL) concentrations.
	detrimental effects to protozoa are found at <u>higher densities</u> of brown tide (>5X10^5 cells per ml $^{-1}$) (Caron et al. 1989) in Long Island Bays; prolonged period of brown tide blooms at higher densities (> 1.0X 10^6 cells ml $^{-1}$) likely to have widespread, detrimental effects on production rates of higher trophic levels via impacts on protozooplankton – similar to Texas brown tide (Buskey & Stockwell 1993); Copepod production was reduced at 7.6 X 10 ^{5} *A. anophagefferens* cells ml $^{-1}$ (Durbin and Durbin 1989) in Narragansett Bay. Preliminary data suggested negative impacts on copepod egg production rates in West Neck Bay, NY after brown tide concentrations reached 1.5 X 10 ^{6} cells ml^{-1} (Lonsdale et al. 1996). \Other taxa negatively affected by brown tide blooms (e.g., Cladoceran populations reduced in Narragansett Bay in 1985) (Smayda and Fofonoff 1989); Meroplanktonic larvae, including polychaetes and bivalves negatively correlated with brown tide concentration and were lower than in non-bloom yrs (Smayda and Fofonoff 1989); decreased abundance of bivalve larvae (*M. mercenaria)* during 1985 bloom in Great South Bay (but not in 1986 – less severe brown tide)(Duguay et al 1989). The absolute and relative abundance of *A. anophagefferens* is critical in determining its impact on grazers in Long Island bay studies – adverse effects on bivalve larvae and adults seems to be induced above a threshold concentration of ≅ 2 X 10^5 *A. anophagefferens* cells ml $^{-1}$ (Bricelj and Lonsdale 1997); Reduced shoot growth of eelgrass in Long Island bays (Dennison et a. 1987) with brown tide blooms of prolonged duration (> 2 months).
Risk Characterization	

Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude) Assessment of severity/irreversibility 1 - No detectable exposure 2 - Ecosystem exposed but structure and function hardly affected 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 5 - Lifeless ecosystems or fundamental change; Irreversible		Score 4

	A. **Benthic Communities** In Peconic Bay, NY, stock enhancement contributed to the partial recovery of scallop stocks (electrophoretic markers) (Krause, unpubl.); effects on other bivalves, such as oysters and quahogs remain poorly documented; poor growth of juvenile hard clams (*M. mercenaria)* during brown tides was reported by several commercial hatcheries (e.g. Bluepoints Inc. W. Sayville, NY and Biosphere Inc., Tuckerton, NJ). The 1999 brown tide bloom in Barnegat Bay was reported to have impacted the hard clams again at Biosphere but was reversed after the bloom subsided. If blooms last longer than 1-2 months, reversibility is reduced or unattainable; Marked differences in susceptibility to brown tide were found within taxa; among bivalves, Highest to lowest sensitivity: *M. edulis > M. mercenaria* 4. Data from 2000-01 monitoring show that concentrations of the brown tide organism are high enough to be damaging to shellfish and eelgrasses in many coastal bays from Raritan Bay south to Great Egg Harbor. Additional sampling in bays south of Great Egg Harbor is necessary. B. **Planktonic Communities** Rapid recovery of aloricate ciliates after brown tide in Long Island Bays, but not of tintinnids during brown tide declines (Mehran 1996). Studies have suggest a threshold phenomena in which predatory-prey interactions (protozoan grazing and production) are disrupted only during peak	

	bloom conditions or when alternate food is lacking (Caron et al. 1989; Lonsdale et al. 1996; Mehran 1996). Prolonged period of brown tide blooms at higher densities (> 1.0 X 10 6 cells ml –1) likely to have widespread, detrimental effects on production rates of higher trophic levels via impacts on protozooplankton – similar to Texas brown tide (Buskey & Stockwell 1993) When brown tide ceased and normal conditions prevailed in Narragansett Bay in 1985, cladoceran abundance returned to normal levels (non-brown tide blooms yrs.) (Smayda and Fofonoff 1989); Tintinnids more severely affected by brown tide blooms than aloricate ciliates. **Blooms lasting 1.5-2 mos: Eelgrass: 4** Hard Clams: 4 **Other shellfish: 4 Protozoan**:3?	
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	**See description in above box.** **Eelgrass: 4** Hard Clams:4 **Other shellfish:4** **Protozoan**: 3?	**5**

Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	Brown tide blooms are a recurring phenomena in southern Barnegat Bay, Little Egg Harbor, Great Bay, coastal bays, and have been found as far south in Great Egg Harbor. In 1999 and 2000, the brown tide blooms were significant and increased severity as compared to blooms in the mid-1990s. Data from monitoring in 2000-01 show that brown tide blooms recur in concentrations harmful to shellfisheries in many coastal bays from Raritan Bay south to Great Egg Harbor Bay. Additional sampling is needed in bays south of Great Egg Harbor. Brown tide could be a **potentially high risk** affecting any shallow bay estuary on the coast with the appropriate conditions.	**4**
	Total	**80**
Assessment of uncertainties in this assessment (H,M,L) and brief description	**L=Low:** Based on extensive studies and data collected in Long Island Bays and Narragansett Bays; conditions in Barnegat Bay are similar to bays in other states where brown tide has persisted over the years; low uncertainty regarding the damage due to prolonged duration of blooms; Medium uncertainty concerning economic and aesthetic impacts as the bloom increases in extent and duration in future years in Barnegat Bay	
Potential for additional data to result in a significant future change in this risk estimate (H,M,L) and a brief description	(High). Data from 2000-01 monitoring has shown that 1) the severest blooms occur in southern Barnegat Bay-Little Egg Harbor-Great Bay area mainly in May-June but can occur again in the fall months; 2) less severe but still damaging blooms occurred from May-November in 2000 and 2001 in many coastal bays including Raritan Bay south to Great Egg Harbor which was the furthest southern reference site. Additional sampling should continue in all coastal bays in the Atlantic, especially in coastal bays south of Great Egg Harbor. Additional data are needed on brown tide occurrence within a set of environmental variables and effects on natural resources. If results of trends analysis are the same as results of Long Island brown tide blooms, then effects and impacts described in this assessment will probably be true of NJ bays. Additional data needed on: Status and trends of brown tide occurrences in Barnegat Bay, Little Egg Harbor, Great Bay and other areas; identification of brown tide occurrences within a range of environmental variables including salinity, temperature, nutrients, etc.; status and trends of eelgrass bed distribution on a yearly basis; studies are needed on the depth at which eelgrass beds grow; status and trends of natural populations of hard clams throughout the year.	
Potential for future change in the underlying risk from this stressor (+++, ++, +,0,-,=,≡) and brief description	**(≡)** Potential for future change in the underlying risk from brown tide stressor depending on additional data. Given the data from Long Island Bays and the observation that brown tide blooms have been observed in NJ since the 1980s, the potential for significant change in the underlying risk could be more negative – but may reduced proportionally to the amount of time-series data collected and analyzed on natural resources. Data are needed on brown tide occurrence,	

	severity, extent, and enumeration, concomitant environmental parameters (esp. salinity, temperature) and time series data collection on impacted populations of eelgrass beds, benthic and planktonic populations.). If the problem appears to be chronic, the potential from this stressor could be more negative. Conversely, if trends data indicate that brown tide blooms are chronic but pose no substantial threats yearly, then the potential could be less negative (or -)
Potential for catastrophic impacts (H,M,L) and brief description	**H=High** potential for catastrophic impacts because the presence of the brown tide organism is considered regional (NY and NJ) and chronic (since the mid-80s) and an index is needed to evaluate the severity, extent and duration of these blooms; the longer the duration of the blooms, the more potential for environmental damage;
Link to other Work Groups (e.g., socioeconomic impacts)	**Economic impacts**: Summer of 1999: public inquiries concerning the advisability of purchasing property along Barnegat Bay at the height of the brown tide bloom in 1999; economic impact on the aquaculture facility during prolonged blooms (> 1 month); 2. Economic losses for the New York State bay scallop fishery resulting from reduced landings attributed to brown tide blooms in Long Island bays were estimated at $2 million per year (Kahn and Rockel 1988). **Aesthetic impacts**: public complaints about the color of the waters of Barnegat Bay during peak summer season may have economic impacts and negatively affect primary and secondary uses (e.g., swimming and boating); reported disappearance of water birds during bloom;
Extent to which threat is currently regulated or otherwise managed	Currently, there is no regular monitoring for brown tide in New Jersey; there is no monitoring for status and trends of eelgrass beds and hard clam distribution in areas where brown tide is occurring. NJDEP/DSRT is conducting a brown tide assessment in 2000 to monitor concentrations of brown tide throughout the year. This assessment should be continued including analysis of parameters and environmental factors related to these blooms. However, in 2000, the Brown Tide Assessment Project was established that conducts monitoring to determine the spatial and temporal extent of the blooms. Approximately 44 water quality stations are monitored six times per year, along with water samples collected by EPA helicopter at six stations biweekly from May through September, and samples are enumerated for brown tide using a newly developed monoclonal analysis. In addition, research on viral infection of the brown tide in field population is underway.
Barriers to restoration	NJDEP monitoring program currently does not routinely monitor harmful algal blooms having only ecological significance (e.g., brown tide); lack of 1998-1999 data on eelgrass bed distribution and extent in Barnegat Bay; lack of NOAA data on brown tide counts in Barnegat Bay during the 1999 bloom year; new monoclonal methods of brown tide enumeration are more rapid and accurate than older polyclonal methods but all enumeration data to date were developed using polyclonal methods. DSRT study in 2000 will use monoclonal techniques to enumerate the brown tide organism.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	No known point/nonpoint sources for brown tide blooms
Large business/industry	
Small business industry	

Transportation	
Residential	
Agriculture	
Recreation	
Resource extraction	
Government	
Natural sources/processes	Brown tide blooms are associated with several hydrographic processes occurring in Barnegat Bay including low flushing times (c. 50 days) or long residence times in shallow estuarine bays, high salinities (> 26 ppt) and possibly, lower than peak summer temperatures (c. 20-25 ^{0}C); while particular nutrients may not affect the blooms, it has been hypothesized that the rates of nutrient loadings may be involved. Both environmental and biological factors need to be studied in relation to these blooms.
Orphan contaminated sites	
Diffuse Sources	
Sediment sinks	
Soil sinks	
Non-local air sources incl. Deposition	
Biota sinks	

Summary Statement: Brown tide blooms, caused by a minute golden-brown alga, *Aureococcus anophagefferens,* are a recurring phenomena in the past few years in southern Barnegat Bay, Little Egg Harbor, Great Bay and south in Great Egg Harbor (Atlantic region). This organism needs elevated salinities from 16-31 parts per thousand with rapid growth. While there are no known human health impacts, brown tide blooms can have substantial ecological impacts (e.g., reduction in growth in hard clams, reduction in eelgrass coverage). While there are numerous hypotheses concerning factors promoting blooms, the causes of brown tide blooms are poorly understood. While nutrients may play some role in these blooms, the occurrence of these blooms appears to be related more to other physicochemical and biological factors. NJDEP's DSRT has established a Brown Tide Assessment Project to assess the spatial and temporal distribution of these blooms in 2000-01. In 2000-01, water samples were collected from Raritan Bay south to below Great Bay. *Aureococcus* were enumerated using monoclonal analysis. Data from 2000-01 monitoring has shown that 1) the severest blooms occur in southern Barnegat Bay-Little Egg Harbor-Great Bay area mainly in May-June but can occur again in the fall months; 2) less severe but still damaging blooms occurred from May-November in 2000 and 2001 in many coastal bays including Raritan Bay south to Great Egg Harbor which was the furthest southern reference site. Additional sampling should continue in all coastal bays in the Atlantic, especially in coastal bays south of Great Egg Harbor.
Additional monitoring is needed to determine the spatial and temporal distributions of the brown tides in NJ coastal bays. Information is needed on the physical conditions that may promote blooms such as salinity, temperature, nutrients, ground water loadings, and local meteorological conditions as well as flushing rates for Little Egg Harbor.

Issue: Brown Tide
Author: M. Gastrich
Version: 05/00

Statewide Analysis of Threat   Threat = Brown Tide

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	N/A	N/A	N/A	NA
Marine Waters	4	5	4	80
Wetlands	N/A	N/A	N/A	NA
Forests	N/A	N/A	N/A	NA
Grasslands	N/A	N/A	N/A	NA
			Total Score	80
			Average Score	16

Risk by Watershed Management Region

THREAT =	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	N/A	N/A	N/A	N/A	N/A
Passaic	N/A	N/A	N/A	N/A	N/A
Raritan	N/A	Low	N/A	N/A	N/A
Atlantic	N/A	High	N/A	N/A	N/A
Lower Delaware	N/A	Low	N/A	N/A	N/A
Region/Watershed (secondary)					
Urban	N/A	Medium	N/A	N/A	N/A
Suburban	N/A	Medium-High	N/A	N/A	N/A
Rural	N/A	Medium-High	N/A	N/A	N/A

H=high, M=medium, L=low;

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.**New Jersey Comparative Risk Project**
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification Stressor:	**Cadmium**
Description of Stressor:	Cadmium, with an atomic number 48, atomic weight 112.4, and density of 8.65 at 25^o C, is an odorless element with a boiling point of 765^o C and a melting point of 321^o C (Prater 1995). It is a soft, silver-white metal with a bluish tinge that is insoluble in water, and is highly corrosion resistant. It is a rare, naturally occurring element in the environment (Wren et al., 1995). In most of the earth's crust it is present at levels below 1 ppm (usually less than 0.2 ppm, making it relatively rare, Farnsworth 1980). Volcanic action is a major natural source of atmospheric cadmium (Hutton 1987). Other natural sources include ocean spray, forest fires, and the release of metal-enriched particles from terrestrial vegetation (Hutton 1987). Cadmium has a variety of uses, including electroplating of automotive, aircraft, and electronic parts, a component of batteries, as a solder for aluminum, and a deoxidizer in nickel plating, and in the engraving process, in electrodes for cadmium vapor lamps and photoelectric cells, in fire protection systems, as a plating and coating agent, and in industrial machinery and marine equipment, and a variety of other uses (Prater 1995). It enters the environment through refining, metal smelting, fuel combustion. Cadmium use by man is relatively recent, dating from the beginning of the 1900s (Hutton 1987). The European Community produces and consumes more cadmium than either Russia and her allies, or than the US (Hutton 1987). Cadmium is carried atmospherically. For example, atmospheric emissions in Canada account for 75 % of the total cadmium losses to the environment (Lymburner 1974). In the transfer of cadmium from terrestrial to aquatic systems, 94-96% remains in the soil, once in the water, cadmium accumulates in the sediments more quickly than in biota (Huckabee and Blaylock 1973). Twenty percent of the cadmium in water remains in suspended particles (Huckabee and Blaylock 1973). Recent advances in analytical capabilities allow assessment of lower levels of cadmium in the environment and in biota than was previously possible. Average total concentrations of cadmium in streams, rivers, and lakes are in the range of less that 0.01 to 0.07µg/l, and total background concentrations in Great Lakes range from less than 0.02 to 0.10 µg/l (Wren et al., 1995). Cadmium is not a biologically essential or beneficial element, but is associated with various deleterious effects. All forms of life, particularly crops, are potentially threatened by cadmium (Prater 1995). Cadmium is a teratogen, carcinogen, and a possible mutagen (Eisler 1985). Freshwater biota are the most sensitive to cadmium; marine organisms are less sensitive than freshwater organisms, and mammals and birds are comparatively resistant to cadmium (Eisler 1985). Daphnid reproduction is reduced 16 % at 0.03 ppm Cd in hard water, but at 0.004 ppm Cd in soft (Prater 1995). Concentrations of 0.9 to 9.9 µg/l in water are lethal to some aquatic insects, crustaceans, and teleost fish, and concentrations of 0.7 to 5 ppb are associated with sublethal effects such as decreased growth, lowered reproduction, and population alterations (Eisler 1985).

	Responses in fish are slow, but eggs and fry are effected by chronic exposure (Prater 1995), and there is a great deal of variation among species (Wren et al., 1995). Salmonids are more sensitive than other fish species (Wren et al., 1995). Safe levels for bluegill is 0.0015, 0.0025 for sunfish (Prater 1995). Sublethal effects in birds include growth deficits, anemia, and testicular damage (Eisler 1985). The kidney is the critical organ for cadmium toxicity. Adverse effects in fish and wildlife are pronounced or probable when cadmium exceeds 3 ppb in freshwater, 4.5 ppb in saltwater, 1000 ppb in the diet, or 100 ug/m^3 in air (Eisler 1985). Liver concentrations in vertebrate kidney or liver that exceed 10 ppm (wet weight) should be viewed causing sublethal effects, and 200 ppm (wet weight) in the kidney is life threatening (Eisler 1985).
Description of stressor [continued]	Several factors modify cadmium toxicity to aquatic organisms, including species, size, age, water hardness, complexation (presence of humic acid), and diet (Wren et al., 1995). Later juvenile stages of fish are more sensitive than embryos, cadmium is less toxic for fish living in hard water (compared to soft), and low water pH reduces cadmium toxicity for algae and fish (Wren et al., 1995). In some species of fish, cadmium concentrations increase with age and size (Thompson 1990). Experimental studies also show that cadmium and calcium play an antagonistic role in the gastrointestinal tract (Chang and Fu 1990). In vertebrates, a calcium-deficient diet enhances the overall toxicity of cadmium (Chang and Fu 1990). There is evidence for bioaccumulation since shellfish concentrate cadmium in nature from 900 to 1,600 times (Prater 1995). However, bioconcentration factors of 2000 to 4000 are reported for mollusks (Pesch and Steward 1980). Median bioconcentration factors for cadmium in macrophytes are less than 50 times, and less than 100 times for fish (Wren et al., 1995). Present evidence is that cadmium accumulates in freshwater organisms, but does not biomagnify up the food chain (Wren et al., 1995), although cadmium levels are higher in organisms that are higher on the food chain for several species of birds (Burger et al., 1984).
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	The impacts are to biological integrity, biodiversity, and ultimately, ecosystem health. However, the biological integrity of freshwater aquatic systems are more threatened by cadmium than are terrestrial systems because of the relative sensitivity of freshwater and some marine organisms compared to birds and mammals (Eisler 1995, Wren et al., 1995). Since there are few reports of cadmium-induced injury to terrestrial wildlife, these ecosystems are less impacted. Although there are no studies on ecosystems, the cumulative effects of cadmium on aquatic organisms, particularly in freshwater, can affect ecosystem functioning. This is particularly true with fish communities since there is great interspecific variability. Since cadmium bioaccumulates, higher trophic levels in freshwater systems are particularly vulnerable.
Key impacts selected (critical ecological effects)	Key impacts are biological integrity and biodiversity, as well as sublethal behavior effects, lowered reproductive success, and tissue concentrations.
Exposure Assessment	

Exposure routes and pathways considered	Exposure is largely to anthropogenic sources and localized contamination from industrial sites and waste sites (waste products from batteries and other sources). Exposure occurs near smelters, plating factories, and other industries. Effluents from a battery plant contaminated a freshwater marsh and bay on the Hudson River. Exposure to cadmium in aquatic and terrestrial systems is primarily through the ingestion pathway, although there is some exposure through respiration (Cooke and Johnson 1996). Chronic exposure is more problematic than acute exposure (Cooke and Johnson 1996). Exposure media include soil, surface water, sediment, and food (invertebrates, fish, Wren et al., 1995, Eisler 1995).
Population(s)/ecosystem(s) exposed statewide	All ecosystems in the state are exposed to cadmium through atmospheric deposition. Aquatic systems (both freshwater and marine) are exposed through point and non-point sources, as well as cycling of cadmium throughout the system. Local emissions from smelters and metal-processing plants can increase exposure of local ecosystems. Anthropogenic inputs have resulted in elevated cadmium levels in some surface water and terrestrial settings, especially in urban/suburban regions. Background Benchmark Values STATE BACKGROUND LEVELS (Fields et al., 1993) A study of background levels was carried out, using 80 soil samples of New Jersey's most common soil types. Overall mean values for cadmium in soil was 0.37 mg/Kg. By region, as follows: Urban 0.05 mg/Kg (dry weight) Suburban 0.08 Rural 0.04 Golf Courses 1.87 Farm 0.23 Soil: 20 mg/Kg (Efroymson et al., 1997a; tested for earthworms). Upper Piedmont: 0.17 mg/Kg (Wong & Sanders 1998). Sediment: freshwater: 0.6 mg/Kg, dry weight (LEL), and 10 mg/Kg, dry weight (SEL) (Persaud et al., 1993). Marine/Estuarine: 1.2 mg/Kg, dry weight (ER-L), and 9.6 mg/Kg, dry weight (ER-M) (Long et al., 1993).

	Surface Water: Freshwater chronic criteria for Cadmium is 1.0 µg/l; Saltwater chronic criteria is (NJ State Water Quality Criteria). Concentrations of 0.8 to 9.9 Cd/L in water are lethal to several species of aquatic insects, crustaceans and fish (Eisler 1985). The LC50 for fish in laboratory settings ranged from 1 µg/l to 7160 µg/l (Wren et al., 1995). Concentrations of 1-3 ppb Cd in water can cause reduction in growth, survival and fecundity of trout (Eisler 1985). Plant Tissues: screening benchmark for phytotoxicity in soil = 4 mg/Kg and in solution = 0.1 mg/L (Efroymson et al., 1997b). Invertebrate Tissues: interpreting levels of all metals, including cadmium, in invertebrates is difficult because toxicity occurs when the rate of uptake exceeds the rates of detoxification and/or excretion, rather than at an absolute body concentration (Rainbow 1996). Thus one invertebrate with a lower level of cadmium may suffer from toxicity while another of the same species has a higher level accumulated in a detoxified form over an extended period. Further, the levels of acute toxicity vary markedly among invertebrates, although the lowest LC50 was 7.0 µg/l (Wren et al., 1995).
Quantification of exposure levels statewide	Fish Tissue: whole body levels of 5 ug/g (ppm, wet weight) are associated with death (Eisler 1985), but data on sublethal levels are not available.
Quantification of exposure levels statewide [continued]	Bird Tissues: cadmium levels of 40 ug/g in the kidney can be considered the threshold concentration for effects, although for seabirds, it may be higher (Furness 1996). Mammalian Tissues: 350 ug/g dry weight in the kidney is the critical level for adverse effects, at least for small mammals (Cooke and Johnson 1996)
Specific population(s) at increased risk	Freshwater invertebrate populations are at increased risk because of their increased sensitivity to cadmium, followed by marine invertebrate populations. Vulnerability of fish depends upon the species of fish (as well as size and age), and physical factors such as hardness. Birds and mammals are both less sensitive to cadmium toxicity, and do not experience biomagnification of cadmium up through the food chain. Ecosystems adjacent to smelters and metal-processing plants with elevated levels of cadmium in the soil, sediment or surface water are at increased risk. Cadmium levels in various ecosystems in the state provide a picture of overall ecosystem levels.

	Inland Waters (11 sites) No detectable levels for surface waters. Detectable levels for sediment concentrations in only 5 of 11 sites; cadmium for these sites = 4.4 mg/Kg. Fresh Water Wetlands (4 sites available, wetland soil concentration given for only one site (Nellie's Pond, Burlington Co.), cadmium of 1.65 mg/Kg (Baseline Ecological Evaluation data set). No detectable levels for surface waters. Estuarine Ecosystems 1. Newark Bay: Sediment - 2.5 mg/Kg (Adams et al., 1998) 2. Lower Harbor: (includes Raritan and Sandy Hook Bays): Sediment = 0.54 mg/Kg (Adams et al., 1998). 3. Passaic River Study Area, 1996). Average sediment cadmium levels of 5.51 mg/Kg (range: 0.39-29) (NOAA 1999). Total cadmium in water, values all less than 1 μg/L (NOAA 1999). 4. Hackensack River None found 5. Lower Delaware River Sediment samples: range from 0.5 to 9.8 mg/Kg (mean of 2.0 mg/Kg for 24 samples)(DRBC 1993)
Quantification of exposure levels to population(s) at increased risk	6. Lower Raritan River Surface water: Expressed as range based on data from three contaminated sites. Cd ranged from 0.2- 45 mg/Kg. Sediment ranged from 2 - 29 mg/Kg (R. F. Weston, 1996). Sediment: range from 0.15 - 3.8 mg/Kg (mean of 1.6 mg/Kg, 10 sites, CDM 1999). 7. Atlantic Coastal Waters (New York Bight, EPA 1997) Surface water: range from 0.02 to 0.09 8. Urban Piedmont (Wong and Sanders 1998) Soil: average values of 0.17 mg/Kg

Quantification of exposure levels to population(s) at increased risk [continued]	Organisms at Risk Aquatic invertebrates are most at risk because they bioaccumulate cadmium and are far more sensitive than vertebrates to cadmium. Species of greatest concern vary depending upon whether one is examining ecosystem effects or ecological services. Shellfish are of great concern from a recreational and commercial standpoint. However, from an ecological risk perspective, a wide range of invertebrates in both marine and freshwater ecosystems are at risk because of their role at the base of the food chain and as the organisms that consume plant material. Ecosystems at Risk Unlike other metals, there are no regions of the state with excessively high cadmium levels from industrial hazardous waste sites or discharge sites. However, because of the high sensitivity of aquatic invertebrates, all aquatic habitats are potentially at risk because these organisms are an integral part of the food chain, there is the potential for point-source pollution, and cadmium is carried atmospherically.
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	Statewide average concentrations of cadmium, or local levels, were compared to screening benchmark values to assess the risk to organisms living in New Jersey's ecosystems. Benchmarks for soil, sediment, surface water, and plant and animal tissue levels were compared to available data on cadmium concentrations for these matrices. The hazard quotient (HQ) method was used to conduct a screening level risk assessment where: $HQ = \frac{\text{Estimated Environmental Concentration}}{\text{Benchmark Concentration}}$ This approach assumes that concentrations of the contaminant were representative of the exposure to biota in the ecosystems evaluated. HQ values < l indicate cadmium concentrations are at a level where adverse effects are not expected and there is little risk. Values > 1 indicate that cadmium concentrations are at a level where adverse effects may potentially occur, and there is potential risk to ecological receptors, which increases with level of the food chain.

Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)	1. Statewide Ambient Sediment Urban HQ = 0.50 mg/Kg = 0.83 0.6 mg/Kg Suburban HQ = 0.08 mg/Kg = 0.13 0.6 mg/Kg Rural HQ = 0.04 mg/Kg = 0.36 0.6 mg/Kg Golf Courses HQ = 1.87 mg/Kg = 0.067 0.6 mg/Kg Farm HQ = 0.23 mg/Kg = 0.38 0.6 mg/Kg 2. Total Cadmium Associated with Contaminated sites and/or enriched urban/industrial settings:	Score 1 1 1 1 1
Risk estimate(s) by population at risk [continued] Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)	Inland Fresh Water: Surface Water: HQ is not a problem because levels were non-detect. Sediment: HQ = 4.4 mg/Kg = 0.73 0.6 mg/Kg Freshwater Wetlands: Surface Water: HQ is not a problem because levels were non-detect. Sediment: HQ = of 0 to HQ = 1.65 mg/Kg = 1.37 1.2 mg/Kg	Score 1 1 1 2

	Estuarine Ecosystems:	
	1. Newark Bay	
	Surface Water: no data available	
	Sediment: HQ = $\frac{2.5 \text{ mg/Kg}}{1.2 \text{ mg/Kg}}$ = 2.08	2
	2. Lower Harbor	
	Surface Water: no data available	
	Sediment: HQ = $\frac{0.54 \text{ mg/Kg}}{1.2 \text{ mg/Kg}}$ = 0.45	1
	3. Passaic River:	
	Surface Water: no data available	
	Sediment: HQ = $\frac{5.51 \text{ mg/Kg}}{1.2 \text{ mg/Kg}}$ = 4.59	2
	4. Lower Delaware River	
	Surface Water: no data available	
	Sediment: HQ = $\frac{2.0 \text{ mg/Kg}}{1.2 \text{ mg/Kg}}$ = 1.67	1
	5. Lower Raritan River	
	Surface Water: HQ = $\frac{0.2\ \mu g/l}{9.3\ \mu g/l}$ = 0.02	1
	Sediment: HQ = $\frac{1.6 \text{ mg/Kg}}{0.6 \text{ mg/Kg}}$ = 1.33	2

Risk estimate(s) by population at risk [continued] Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)	6. Atlantic Coastal Waters – (NewYork Bight). Surface Water $HQ = \frac{\text{max of } 0.09\ \mu g/L}{1.0\ \mu g/L} = 0.1$ 7. Urban (Piedmont) Soil Water: $HQ = \frac{0.17\ mg/Kg}{0.6\ mg/Kg} = 0.28$ RISK SCORES: HQ – SCORE < 1 – 1 1-5 – 2 6-10 – 3 11-25 – 4 25+ – 5	Score 1 1
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: - many species threatened/endangered - major community change - extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: - all habitats intact and functioning - population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly	See attached Table for statewide analysis	

Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 - Occasional 2 - Rare 1 - Possible in the future 0 - Unlikely (or 0.1)	See attached Table for statewide analysis	
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	See attached Table for statewide analysis	
	Total	

Assessment of uncertainties in this assessment (H,M,L) and brief description	There is moderate uncertainty with this assessment, largely due to the infrequent sampling of media and the limited spatial extent of the sampling. There is limited data on statewide sampling, and on surface water, sediment and tissues (fish and other vertebrates). All habitats in the state are not covered. Some of the data had detection limits that were greater than the screening criteria. The risk to aquatic life may be underestimated.
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	Unfortunately there is no regular monitoring of cadmium levels in the state in any media (surface water, sediment, soil), and no regular monitoring of biota that would be necessary to examine risks. Monitoring of invertebrates should be undertaken, particularly given the importance of some shellfish to recreational and commercial interests, and the importance of invertebrates to the food chain. Given the high HQs for sediment, additional work with benthic invertebrates that live in sediment is essential. Additional data may change the risk estimates, particularly for invertebrates. Additional data from vertebrates are essential to understand the risk to wildlife populations from cadmium in the environment.

Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, –, =, ≡; where + is improvement), and brief description.	(–) The potential for significant future change in the underlying risk for cadmium is low. Cadmium does not degrade, and continued point-source and non-point source pollution, in addition to atmospheric deposition, could result in increased levels in soil, surface waters, and sediments, with increased exposure to aquatic invertebrates that are most at risk. Unless steps are taken to reduce sources, impacts on aquatic invertebrates may increase in the future.
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L: The potential for catastrophic impacts to NJ's ecosystems and associated biota is considered low based on current releases rates, the fate of cadmium, and current knowledge of the adverse effects.
Link to other Work Groups (e.g., socioeconomic impacts)	Potential socioeconomic impacts of cadmium contamination include the economic costs of loss of shellfish to recreational and commercial fisheries, secondary losses to interests dependent on tourism and recreation, and losses of biodiversity.
Extent to which threat is currently regulated or otherwise managed	Control of cadmium discharges and the remediation of cadmium-contaminated hazardous waste sites are regulated under the Industrial Site Recovery Act (ISRA), Spill Compensation and Control Act, Solid Waste Management Act (SWMA), Water Pollution Control Act (WPCA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended by Superfund Amendments and Reauthorization Act of 2986 (CERCLA) and the Hazardous Site Discharge Remediation Act.
Barriers to restoration	Continued atmospheric releases and subsequent deposition from smelters and other industries provide a barrier to restoration.
Relative Contributions of Sources to Risk (H,M,L); include any information/ details on sources	The primary sources to NJ ecosystems appear to be atmospheric deposition, point source pollution from smelters and from historical industrial discharges. The combination of atmospheric deposition, pollution, and run-off results in contamination of NJ's aquatic ecosystems, and soils around historical industrial sites.
NJ Primary Sources	
Large business/industry	H: a source of cadmium emissions to the atmosphere is smelting, plating and other industries. These products are used by many people in the state.
Small business industry	H: same as above.
Transportation	L: not relevant.
Residential	M: but some use in paints, batteries that are carelessly discarded and other home uses.
Agriculture	L: mostly from past historical agricultural practices.
Recreation	L.
Resource extraction	L.
Government	L.

Natural sources/processes	L: from volcanic activity and erosion.
Orphan contaminated sites	M.
Diffuse Sources	
Sediment sinks	M. Historical industrial activity including air and water discharges have resulted in elevated cadmium in sediments and water of aquatic systems.
Soil sinks	L. Except near industrial plants.
Non-local air sources incl. deposition	M. Atmospheric deposition in the state is still problematic.
Biota sinks	M. Bioconcentration in aquatic organisms is key, particularly invertebrates which are more at risk than vertebrates.

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Issue: Cadmium
Author: J. Burger
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Statewide Analysis of Threat				Threat = Cadmium
Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	3	3	3	27
Marine Waters	3	3	3	27
Wetlands	3	3	3	27
Forests	2	3	3	12
Grasslands	2	3	3	18
			Total Score	111
			Average Score	22.2

Risk by Watershed Management Region					
HREAT = Cd	*ECOSYSTEM*				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	M	NA	LM	L	L
Passaic	M	M	LM	L	L
Raritan	M	M	LM	L	L
Atlantic	M	M	L-M	L	L
Lower Delaware	M	M	L-M	L	L
Region/Watershed (secondary)					
Urban	M	M	M	NA	NA
Suburban	L	L	L	L	L
Rural	L	L	L	L	L
H=high, M=medium, L=low, NA = not applicable					

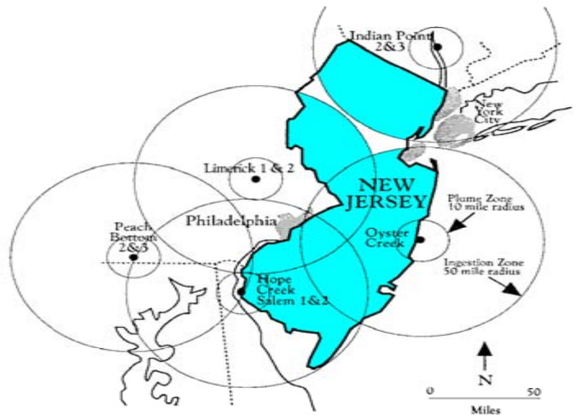
New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	**Catastrophic Radioactive Release**
Stressor	The effects of ionizing radiation from a catastrophic nuclear accident on the environment.
Description of stressor	A prolonged release to the atmosphere as a result of a catastrophic accident at a commercial nuclear powered generating station, where large quantities of radioactive substances consisting of gases, aerosols and particles are released to the environment. The release is high in quantity, involving a large fraction of the radioactive product inventory in the reactor, and its duration is long, defined as lasting for more than a week. (EPRI presentation, G. Vine September 10, 1986)
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	Detrimental effects on the environment have been observed as a consequence of plants and animals having received short-term, very high radiation doses following major accidental releases of radionuclides. *(IAEA Bulletin vol. 39, no. 1 (March 1997). Article entitled Radiation and the environment: Assessing effects on plants and animals.)*
Key impacts selected (critical ecological effects)	The forest and water environment: Because of the high filtering characteristics of trees, deposition is often higher in forests than in other areas. An extreme case was the so-called "red forest" near to the Chernobyl site where the irradiation was so high as to kill the trees, which had to be buried as radioactive waste. In more general terms, forests, being a source of timber, wild game, berries and mushrooms as well as a place for work and recreation, continue to be of concern in some areas and are expected to constitute a radiological problem for a long time. In an accident, radionuclides contaminate bodies of water not only directly from deposition from the air and discharge as effluent, but also indirectly by washout from the catchment basin. Radionuclides contaminating large bodies of water are quickly redistributed and tend to accumulate in bottom sediments, benthos, aquatic plants, dams and fish. http://www.nea.fr/html/rp/chernobyl/allchernobyl.html *(Nuclear Energy Agency Radiation Protection: Chernobyl Ten Years on Radiological and Health Impact, Nov. 1995)*
Exposure Assessment Exposure routes and pathways considered	 It is estimated that 100 per cent of the core inventory of the noble gases (xenon and krypton) can be released, and between 10 and 20 per cent of the more volatile elements of iodine, tellurium and cesium.

	For terrestrial species, the three major pathways are: 1. External radiation from radionuclides from cloud or from radionuclides deposited on the ground. 2. Internal radiation from inhalation of radionuclides or resuspended contaminated particles. 3. Internal radiation from intake of contaminated food products. Radionuclides can enter plants via the roots or be absorbed directly if deposited on the leaves. Radionuclide accumulations in plant leaves provide a food source for grazing animals. Radionuclides are found in a variety of animal tissues depending on the physiology of the animal. Mobile radionuclides such as radiocesium are absorbed and distributed throughout the body, with muscles containing the highest proportions. Less mobile radionuclides, such as plutonium, are poorly absorbed and found mainly in the liver and bone. (*Radioecology Group at ITE Merlewood, 1979*) Pathways between atmospheric-terrestrial-marine ecosystems have been identified e.g., seaspray, as a way to transfer transuranic elements from sea to land. In connection with radioecological studies of the Arctic seas the possible transport of contaminated coastal sediments by seaice has been considered. *(International Atomic Energy Agency, Vienna 1990. Environmental contamination following a major nuclear accident, Vol. 1.)*
Population(s)/ecosystem(s) exposed statewide	There is a wide range over which organisms are sensitive to the lethal effects of radiation. A general classification has been devised based on the interphase chromosome volume of sensitive cells. Plants show a wide range of sensitivity that generally overlaps that of animals. Least sensitive to acute radiation exposures are mosses, lichens, algae and micro-organisms, such as bacteria and viruses. Sensitivity of the organism to radiation depends on the life stage at exposure. Overall, the available data indicate that the production of viable offspring through gametogenesis and reproduction is a more radiosensitive population attribute than the induction of individual mortality. *(IAEA Bulletin vol. 39, no. 1, March 1997, Article entitled Radiation and the environment: Assessing effects on plants and animals.)*
Quantification of exposure levels statewide	All living organisms exist and survive in environments where they are subject, to a greater or lesser degree, to radiation from both natural and anthropogenic sources. There are additional increments of radiation exposures either from authorized (controlled) discharges of radioactive wastes to the air, ground, or aquatic systems or from accidental releases. *(IAEA Bulletin vol. 39, no. 1 (March 1997). Article entitled Radiation and the environment: Assessing effects on plants and animals)*
Specific population(s) at increased risk	Radiosensitivity: There is a wide range over which organisms are sensitive to lethal effects of radiation. A general classification has been devised based on the interphase chromosome volume of sensitive cells. These and other results of experimental irradiations show mammals to be most sensitive, followed by birds, fish, reptiles, and insects. Sensitivity of the organism to radiation depends on the stage of life at exposure. Embryos and juvenile forms are more sensitive than adults. Fish embryos, for example, have been shown to be quite sensitive. The various developmental stages of insects are quite remarkable for the range of sensitivities they present. Overall the available data indicate that the production of viable offspring through gametogenesis and reproduction is a more radiosensitive population attribute than the induction of individual mortality

	.*(IAEA Bulletin vol. 39, no. 1 March 1997, Article entitled Radiation and the environment: Assessing effects on plants and animals*)	
Quantification of exposure levels to population(s) at increased risk	Following severe accidents, however, damage has been observed in Individual organisms and populations, and long-term effects could develop in communities and ecosystems from the continuing increased chronic irradiation. *(IAEA Bulletin vol. 39, no. 1 March 1997, Article entitled Radiation and the environment: Assessing effects on plants and animals)*	
Dose/Impact-Response **Assessment**		
Quantitative impact-assessment employed	The objective is to facilitate the validation of assessment models for radionuclide transfer in the terrestrial, urban and aquatic environments. This will be achieved by acquiring suitable sets of environmental data from the results of the national research and monitoring programs. The validation will include data collection and scenario formulation, calculations by modelers and analysis of results. *(International Atomic Energy Agency, Vienna 1990. Environmental contamination following a major nuclear accident, Vol. 1.)*	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced	Radiosensitive populations, i.e. fish embryos – Radiosensitive plants Plants in general Animals with developing gonads Localized concentrations within an organism	4

Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	The frequency of an accident is possible in the future. As result of the Three Mile Island Unit 2 accident, the NRC has established new requirements for commercial nuclear powered generating stations. They are as follows: 1) Sweeping changes involved emergency response planning, reactor operator training, human factors engineering, radiation protection, and many, other areas of nuclear power plant operations. 2) Expansion of NRC's resident inspector program – first authorized in 1977 whereby at least two inspectors live nearby and work exclusively at each plant in the U.S. to provide daily surveillance of licensee adherence to NRC regulations. 3) The establishment of the Systematic Assessment of Licensee Performance (SALP) program to integrate NRC observations, findings, and conclusions about licensee performance and management effectiveness into a periodic, public report. http://www.nrc.gov/OPA/gmo/tip/tmi.htm However, in the past several years the utilities were able to gain life extensions for operating plants and petition the US congress and successfully convince the legislature that this form of oversight was overly burdensome and congress decreased funding for plant inspection programs. As a result of the decrease funding the NRC recently revised its (reactor oversight process) ROP. http://www.nrc.gov/NRC/COMMISSION/SECYS/2000-0049scy.html - _1_2	1

	Effective April 2000 the new inspection program operates with less inspectors, fewer inspections and less oversight. The DEP monitors the performance indicators that are part of this oversight process. The future will confirm the viability of the program, but the DEP will play a strong role in ensuring that the assessment of frequency does not increase above a rating of 1, possible in the future.	
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	>50% of the State/population impacted as depicted below  There are four nuclear power plants operating in New Jersey; Oyster Creek in Forked River and Salem 1 & 2 and Hope Creek in Salem, New Jersey and six outside of the State; in Pennsylvania, Peach Bottom 1&2, and Limerick 1&2, also in New York Indian Point 1&2. The rings are the 10 and 50-mile Emergency Planning Zones for each site.	5
	Total	20
Assessment of uncertainties in this assessment (H,M,L) and brief description	Low NRC Revised Reactor Oversight Process; The main objective of this process was to save money, the electric utilities were	

	able to petition the congress to cut the NRC budget and therefore reduce the enforcement processes. http://www.nrc.gov/NRR/OVERSIGHT/OVERVIEW/pilotguidelines.html
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	Low Significant departure from the way commercial nuclear powered generating station are inspected such as the new Reactor Oversight Process (ROP). http://www.nrc.gov/NRR/OVERSIGHT/
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, ! , =, ≡; where + is improvement, and brief description.	(!) Possible, due to the older nuclear facility staying on line longer than expected.
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	Low – stringent regulations, engineering design, and defense in depth
Link to other Work Groups (e.g., socioeconomic impacts)	Health Work Group
Extent to which threat is currently regulated or otherwise managed	In the United States, the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), the Department of Energy and the Department of Transportation are the principal federal agencies responsible for establishing radiation protection regulations. These agencies work with international organizations to assure that their regulations are based on internationally recognized scientific studies. Two series of reports provide much of the data used in setting radiation standards. The reports are produced by the National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation (NAS/BEIR) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Both UNSCEAR and NAS consider new data, as it becomes available from studies of exposed populations. When the data indicates that the risk estimates should be revised, either up or down, the committees prepare new reports to reflect this.
Barriers to restoration	None
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	Nuclear power industry
Small business industry	N/A
Transportation	N/A
Residential	N/A

Agriculture	N/A
Recreation	N/A
Resource extraction	N/A
Government	N/A
Natural sources/processes	N/A
Orphan contaminated sites	N/A
Diffuse Sources	
Sediment sinks	N/A
Soil sinks	N/A
Non-local air sources incl. Deposition	N/A
Biota sinks	N/A

Issue: Catastrophic Radioactive Release
Author: Di Nucci/Tuccillo
Version: 07/31/00

Statewide Analysis of Threat

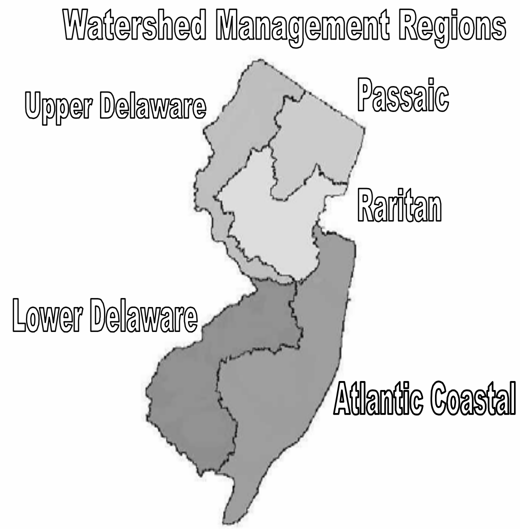
Threat = Catastrophic Event - Radiation

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	4	1	5	20
Marine Waters	4	1	5	20
Wetlands	4	1	5	20
Forests	4	1	5	20
Grasslands	4	1	5	20
			Total Score	100
			Average Score (Total ÷ 5)	20

Risk by Watershed Management Region

THREAT = Catastrophic Event - Radiation	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	H	NA	H	H	H
Passaic	H	H	H	H	H
Raritan	H	H	H	H	H
Atlantic	H	H	H	H	H
Lower Delaware	H	H	H	H	H
Region/Watershed (secondary)					
Urban	H	H	H	H	H
Suburban	H	H	H	H	H
Rural	H	H	H	H	H

H=high, M=medium, L=low, NA = not applicable


Watershed Management Regions
Upper Delaware
Passaic
Raritan
Lower Delaware
Atlantic Coastal

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Stressor:
Channelization

Issue Summary: Channelization is the human alteration of the natural streambed and channel of streams and rivers. Negative impacts include loss of habitat, increased flow and erosion, changes in aquatic populations, increased water temperature and other physical and chemical changes. More than 200,000 miles of U.S. waterways were channeled or modified between 1820 and 1970. This assessment examined the channelization of non-tidal freshwaters. Channelization has occurred in NJ's waterways, especially in urban areas. Projects are currently underway that will have negative impacts on the stream ecosystems, however unlike historical projects, these projects include mitigation of impacts.

Severity: Overall: Low (Inland Waters: L-M)

Uncertainty: Low to moderate. The impacts of channelization have been well described in the literature, however the exact extent and location of channelization is NJ and associated impacts have not been adequately characterized.

Potential for Catastrophic Impact: Low

Trend: (Potential for future changes in the underlying risk from this stressor): (+) Current practices require mitigation or avoidance of impacts; therefore future projects should have reduced impacts compared to historical projects. Restoration of streams is growing at both the private and state/federal government level. A number of programs are improving stream banks, and stream and riparian habitat (e.g., NJDEP 319(h) grants). Increases in the amount of restored streams will help mitigate past impacts and practices.

Introduction: Channelization refers to the alteration of the natural streambed and channel of brooks, streams and rivers. This can include activities such as straightening, widening, deepening, relocating stream channels, and clearing or snagging operations (EPA, 1999). These alterations are typically undertaken for flood control, navigation, drainage improvement, and reduction of channel migration potential (Brookes, 1990 in EPA, 1999). Often channelization results in a straightening of a stream, with associated loss of habitat. This also leads to increased flow velocity and associated erosion of the stream bank or sediments, and loss of riparian vegetation. In some cases (e.g., urban areas), the natural stream channel is replaced with an artificial substrate (e.g., concrete), resulting in almost complete elimination of the benthic invertebrate community. More than 200,000 miles of U.S. waterways were channelized or modified between 1820 and 1970 (Schoof, 1980).

The formation and characteristics of natural steam channels are a complex geomorphological process. In a river valley, the stream channel meanders across the valley floor, with erosion and deposition processes occurring simultaneously at different points along the stream. This results in "movement" of the channel location towards the eroding side of the stream. Channelization disturbs that process and has profound effects on the physical, chemical, and biological characteristics of the stream.

This assessment examines the impacts of channelization on non-tidal freshwater streams in NJ. Channelization in tidal waters is primarily dredging of navigation channels and is covered under a separate assessment (i.e., dredging).

Effects: Stream channelization can adversely affect biological integrity, biodiversity, habitat/ecosystem health, and ecosystem function. These include (White, 1996; EPA, 1999):
Accelerated erosion/changes in sediment supply
Alteration of hydraulic variables (e.g., slope, depth, width, & channel roughness) resulting in disruption of dynamic equilibrium of the river

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Version: 12/01

Alteration/losses of wetlands due to changes in floodplain hydrology
Accelerated delivery of pollutants
Reduced freshwater availability
Changes to ecosystems including:
Loss of instream habitat
Loss of riparian habitat
Deterioration of spawning habitat
Changes in types and amounts of food organisms.

Some of these effects can have negative or positive impacts (e.g., decreased sediment in a streambed resulting in better spawning habitat) on a stream system, depending on the existing conditions and aquatic life present. However, in general these types of changes result in negative impacts to the existing ecosystem.

New Jersey Waterways: In New Jersey "Channelization" means any artificial reconstruction of the bed and/or banks such as by straightening, lining, deepening or piping (N.J.A.C. 7:13-1.1).

Within the state's 7,788 square miles are 127 miles of coastline; 8,020 miles of rivers and streams and 113 square miles (72,590 acres) of lakes and ponds larger than 2 acres. In addition, there are 1,482 square miles of fresh and saline marshes and wetlands, and 725 square miles of estuarine waters including tidal rivers (NJDEP, 2000). New Jersey waterways have been modified for flood control, drainage improvement, navigation, and other reasons (e.g., urbanization), however an accurate estimation of the percentage of channelized streams was not available for this assessment. A historical accounting of channelization and flood projects in the state was beyond the scope of this assessment.

All streams in the northern portion of New Jersey, i.e. the Piedmont, Valley / Ridge and Highlands regions, are considered to be “high gradient” streams, having substrates of rock and cobble of various sizes, and with relatively swift flow. Those in the Coastal Plain region of southern New Jersey are considered as “low gradient” streams, having slower flow and more homogeneous substrates, primarily of sand or gravel and finer sediments. The transition from high gradient to low gradient is marked by the “Fall Line”, a geologic/topographic feature, which bisects New Jersey in a southwest – northeasterly direction from the Delaware River at Trenton through the lower Raritan River near New Brunswick (NJDEP, 2000).

Flood control projects are primarily conducted by the U.S. Army Corps of Engineers (USACE) with a local or state co-sponsor. The USACE New York District currently has approximately 22 flood control projects in various phases (e.g., design, feasibility, and construction) in New Jersey (USACE, 2001). One of the largest is the Green Brook flood control project in Somerset, Union, and Middlesex counties. This $366 million 12-year project consists of 14 miles of levees and floodwalls, two dry detention basins, 3 miles of channel modification, bridge construction, and buyout of up to 22 homes and 3 businesses. The detention basins and 2 miles of channel modifications have been deferred at the request of the State of NJ (USACE, 2001).

The Green Brook project acknowledges the presence of valuable natural resources (USACE, 2001). The project plan was developed to: 1) avoid impacts to natural resources; 2) minimize impacts to natural resources; and 3) provide mitigation where impacts are unavoidable. Approximately 0.28 square miles of natural resources are being adversely impacted. The USACE has identified 39 potential sites for mitigation totaling 2.27 square miles. Projects conducted prior to the 1970’s did not typically require mitigation.

Channelization is only one factor that can impact stream ecosystems. New Jersey monitors freshwater streams through the Ambient Biomonitoring Network (AMNET; NJDEP, 2000). Based on Rapid Bioassessment Protocols (RBP), each stream is rated as non-impaired, moderately impaired, or severely impaired. NJDEP samples over 800 stream sites statewide once every five years. There are a number of factors that impact streams that have been identified by this program. Environmental factors that may adversely affect stream biology, including both chemical and physical parameters, are listed below (NJDEP, 2000):

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1. Lack of dissolved oxygen
2. Higher than normal temperature
3. Excessive turbidity
4. Presence of toxicants (in various chemical forms)
5. Eutrophication (= excessive nutrients promoting undesirable vegetation or algal blooms, and increased turbidity)
6. Degraded habitat
a. lack of bank vegetation/canopy (= poor bank stability, lack of shade)
b. excessive sedimentation (= poor substrate and water clarity)
c. lack of streamflow (= low dissolved oxygen, possible sedimentation, undesirable vegetation)

Inter-related human activities or practices, land uses, and natural features or events contributing to degraded stream quality:

1.Deforestation/development/construction (largely via runoff from non-point sources)
2. Urbanization/industrialization (largely via runoff from non-point sources)
3. Agricultural operations (largely via runoff from non-point sources)
4. Municipal or industrial wastewater discharge (point source)
5. Artificial channelization or habitat alteration
6. Upstream impoundment, lake or pond
7. Drought conditions

Other NJDEP reports have indicated that aquatic life impairments have been generally attributed to water quality, sediment quality, habitat alterations (e.g., erosion, sedimentation), flow alterations (e.g., flashiness, low or high flows, drought), and natural population shifts (NJDEP, 2001).

In summary, NJ's waterways have been impacted by channelization, with the majority of impacts most likely occurring historically, primarily in urban areas, prior to regulatory controls and mitigation. An assessment of the historical impacts was not attempted and beyond the scope of this project. It can be argued that impacts continue to occur in these channelized streams due to various physical changes (e.g., changes in substrate, loss of riparian vegetation). In addition, new flood control projects will have impacts on the streams, however these projects require the minimization/avoidance of impacts to natural resources and mitigation.

Management: Currently disturbances to streams require Stream Encroachment permits from the NJDEP under the Flood Hazard Area Control Act (N.J.S.A. 58:16A). This permit process limits the amount of disturbance to streams and associated floodplains. Disruption or loss of wetlands requires mitigation under NJ's Freshwater Wetlands Protection Act (N.J.S.A. 13:9B). This and other factors have led to a reduction in stream channelization. However, in the case of flood control projects sponsored by the federal and local/state governments, modification of streams does occur in instances such as flood control (e.g., Army Corps of Engineers' projects). Current practices require minimization of impacts to natural resources and mitigation of unavoidable impacts.

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Version: 12/01

Statewide Analysis of Threat Threat = Channelization

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	3	2	18
Marine Waters	2	2	1	4
Wetlands	3	3	2	18
Forests	NA	NA	NA	NA
Grasslands	NA	NA	NA	NA
			Total Score	40
			Average Score (Total ÷ 5)	8

Risk by Watershed Management Region

THREAT = Channelization	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L	NA	L	NA	NA
Passaic	M	M	M	NA	NA
Raritan	M	M	M	NA	NA
Atlantic	L-M	L	L-M	NA	NA
Lower Delaware	L-M	L	L	NA	NA
Region/Watershed (secondary)					
Urban	M-H	M	M	NA	NA
Suburban	M	L	M	NA	NA
Rural	L	L	L	NA	NA

H=high, M=medium, L=low, NA = not applicable

Issue: Channelization
Author: Buchanan
Version: 12/01

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Chromium (Cr^{3+} and Cr^{6+})**
Description of stressor	Chromium, with atomic number 24 and atomic weight 52.0, averages 100 ppm in the earth's crust (Matzat and Shiraki 1974, in Demarest 1995) and normally ranges from trace levels to 300 ppm (Langaard and Norseth 1979; Towill *et al.,* 1978, in Demarest 1995). The most common natural form of Chromium is Chromite ore ($FeCr_2O_4$). The two valence states commonly found in natural systems are trivalent Chromium (Cr^{3+}) and hexavalent Chromium (Cr^{6+}). Total Chromium levels are typically elevated in environmental media in the vicinities of electroplating, metal finishing, and tanning industries, as well as publicly owned domestic wastewater treatment plants (Eisler 1986). Total Chromium is determined through routine laboratory analyses; speciation can be accomplished through special analytical services that analyze for Cr^{6+}, with Cr^{3+} calculated by difference. Cr^{3+} is generally considered the dominant form in nature, with Cr^{6+} being present at very low levels, due to various physico-chemical conditions (pH, redox, presence of organic materials, etc); Cr^{6+} is a strong oxidizer, and in the presence of organic matter is readily reduced to Cr^{3+}. The solubility of Chromium in water plays an important role in its toxicity. Cr^{3+} is usually not soluble in water, while Cr^{6+} is soluble. Cr^{3+} is generally considered less toxic than Cr^{6+} since it does not readily pass through biological membranes and is non-corrosive. Nonetheless, the literature attributes significant toxicity from Cr^{3+} and Cr^{6+} to freshwater and estuarine/marine microflora, macrophytes, invertebrates and fish. Some aquatic microflora are very sensitive to Chromium. Concentrations of Cr^{6+} as low as 1.0 µg/l and 2.0 µg/l are acutely toxic to the freshwater algae *Euglena gracilis* and *Microcystis aeruginosa*, respectively. The growth rate of *Thalassiosira pseudonana*, an estuarine diatom, was reduced by 50% when exposed to 1.0 µg/l of Cr^{6+} (Government of Canada 1994). Growth was inhibited in the marine algae, *Olisthodiscus lutens* at concentrations of 10 µg/l Chromium (Eisler 1986). Frond growth in the common freshwater duckweed, *Lemna minor*, was reduced after exposure to 10 µg/l Cr^{6+} for 14 days (Eisler 1986). For *Daphnia magna* exposed to Cr^{3+}, the LC50 was 6 µg/l; *D. magna* exposed to 2.5 µg/l of Cr^{6+} for 7 days caused a 28% reduction in juvenile survival and a 22% reduction in the number of young produced (Government of Canada 1994). Available information indicates that fish are more sensitive to Cr^{3+} than Cr^{6+}. Rainbow trout eggs and spermatozoa exposed to 5 µg/l of Cr^{3+} reduced the fertilization rate by 60-70%. The mean 96 hour LC-50 for Cr^{3+} has been reported to be about four-fold lower than that for Cr^{6+} in salmonoid fish, with their reproductive cycles being particularly sensitive to Cr^{3+} (Government of Canada 1994).

	Cr^{6+} concentrations from 16 to 21 µg/l resulted in reduced growth of rainbow trout and chinook salmon fingerlings during exposure for 14 to 16 weeks. Eisler (1989) reports that individual tissues of most species of finfish contain between 0.1 and 0.6 mg/kg, fresh weight. Eisler also reports the accumulation of Chromium under controlled conditions for two marine species, the speckled sanddab and Atlantic croaker. A literature review by Demarest (1995) indicated few field or laboratory studies on birds and mammals which demonstrated injury associated with Cr^{3+}; several laboratory feeding studies which showed some effect involved invasive administration techniques and high concentrations of soluble Cr^{3+} salts. In normal terrestrial field conditions, soluble Cr^{3+} is immobilized or made less available by normal soil pH and the binding capacities of colloids, soil particles, and organic ligands. Mammals are generally considered to be more sensitive to Cr^{6+} than to Cr^{3+}. Cr^{6+} has been investigated by short-term/subchronic studies in which animals have been administered Cr^{6+} by ingestion; effects were observed on the liver, kidney, and hematological parameters. Inhaled Cr^{6+} has been shown to be carcinogenic to experimental animals. Studies of the effects of Cr^{6+} on domestic birds are scarce (Government of Canada 1994). Despite the binding capacities of soil, a number of pot and field studies indicate Chromium phytotoxicity. The greatest potential for Cr^{3+} toxicity to plants under natural conditions appears to be within sandy soils with low pHs and little organic matter, and poorly drained (hydric/wetland) soils with decaying organic matter. Cr^{6+} has been shown to be more toxic to plants than Cr^{3+}. When added to sandy soils, 5 mg/kg Cr^{6+} induced chlorosis, retarded stem development, and inhibited uptake of micronutrients (Government of Canada 1994). There is little evidence for biomagnification of Chromium through the food chain.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	The impacts considered are biological integrity and biodiversity. Chromium levels elevated beyond natural background may cause acute or chronic toxicity, leading to changes in the composition, diversity, and function of normal plant and animal populations and communities.
Key impacts selected (critical ecological effects)	Key impacts evaluated are biological integrity and biodiversity. These impacts are evaluated via the comparison of Chromium analytical data from various media with ecotoxicologically-based acute and chronic NJ Surface Water Quality Standards, sediment quality guidelines, and soil benchmarks.
Exposure Assessment	
Exposure routes and pathways considered	Exposure pathways result from natural background and diffuse anthropogenic sources as well as localized contamination of environmental media from industrial sites. Soil contamination is caused by direct placement of hazardous waste, discharges or spills, and the presence of historic fill containing residues from Chromate ore processing. Aquatic contamination is via point or non-point source discharges, including wastewater treatment effluents, surface water runoff or direct discharge from contaminated property, discharge of contaminated groundwater to surface water and/or wetlands, or leaching from contaminated fill. The primary exposure route for Chromium in the terrestrial and aquatic ecosystem is ingestion (dietary and incidental). Exposure media include soil, surface water, sediment, and food.
Population(s)/ecosystem(s) exposed	All ecosystems in the state are exposed to Chromium since it is a natural component of the soil and sediment. Anthropogenic inputs

statewide	have resulted in elevated Chromium levels in many surface water bodies and terrestrial settings, especially in urban/industrial areas.
Quantification of exposure levels statewide	**Statewide exposure to ambient/natural background and enriched levels of Chromium are discussed as follows. Concentrations for solid matrices are reported on a dry weight basis.** Ambient Total Chromium Exposure Levels Ambient concentrations of inorganic constituents in environmental media result from in situ weathering of parent geological material as well as from a wide variety of diffuse anthropogenic sources, such as atmospheric deposition from industrial emissions. Ambient total chromium levels were measured in 14 river basins throughout the state and presented in Water Resources Data, New Jersey (USGS 1998). Surface water concentrations were measured at 41 stations; with two exceptions, all data were <1.0 µg/l. In the Raritan River Basin at Ironia, the total chromium concentration was 7.3 µg/l. In the Delaware River Basin, the total Chromium concentration was 2.5 µg/l. Eckenfelder, Inc. (1993) reports a range of 3.5-4.6 µg/l total Chromium in the Hackensack River. Sediment concentrations of total chromium was measured at 22 stations; with three exceptions, all data were 10 mg/kg or less. In the Raritan River Basin at Somerville, the total chromium, concentration was 40 mg/kg. At two locations in the lower Delaware River Basin, total Chromium levels were 50 and 30 mg/kg at Jobstown and Glendora, respectively (USGS 1998). New Jersey soil background average total Chromium levels are reported to be 12.06 mg/kg in urban settings, 9.89 mg/kg in suburban settings, 8.35 mg/kg in rural settings, 22.35 in golf course settings, and 9.73 in agricultural settings (Fields et al., 1992). Benchmark Values Sediment: Total Chromium Freshwater-26 mg/kg (LEL) and 110 mg/kg (SEL) (Persaud et al., 1993) Marine/Estuarine –81 mg/kg (ER-L) and 370 mg/kg (ER-M) (Long et al., 1995) Surface Water: Chromium $^{3+}$ Freshwater (aquatic, chronic) – 180 µg/l Marine/Estuarine – not available Surface water: Chromium $^{6+}$ Fresh water (aquatic, chronic) – 10 µg/l Marine/Estuarine (aquatic, chronic) - 50 µg/l (NJDEP 1997) Soil: Chromium $^{3+}$ - 200 mg/kg (based on phytotoxicity) (Demarest 1995)
Specific population(s) at increased risk	The benthic macroinvertebrate community in several surface water bodies in urban/industrial settings or adjacent to contaminated

	sites Or other historic point or non point-sources are at increased risk. These surface water systems show sediment Chromium levels greater than the state-wide ambient exposure levels. Plant and animal communities in Hudson County in the vicinity of historic fill containing Chromium ore processing residue may be at increased risk.
Quantification of exposure levels to population(s) at increased risk	Chromium Exposure Levels Associated with Contaminated Sites and Urban/Industrial Settings (above Statewide ambient/background levels) For inland fresh water and fresh water wetlands, data associated with contaminated sites are used to represent exposure of elevated chromium levels to aquatic receptors. Statewide enriched Chromium exposure levels were estimated from the average or 95% upper confidence level (UCL) sediment and surface water concentrations associated with a limited number of sites representing these ecosystems. The sites chosen for this evaluation have undergone and Baseline Ecological Evaluation (BEE) and or full Ecological Risk Assessment, pursuant to N.J.A.C.7:26E-3.11 and 4.7, with data generated by certified laboratories and validated in accordance with USEPA and State protocols. While remedial actions may have been performed at some of these sites, the data are judged to be good estimates of likely exposure levels caused by contaminated sites statewide. Average or 95% UCL Total Chromium surface water and sediment concentrations associated with contaminated sites are as follows: Inland Fresh Waters: **(10 sites, data summaries attached)** Surface Water: 4.9 µg/l Sediment: 89.0 mg/kg **Fresh Water Wetlands**: 43.6 mg/kg total Cr (one site, data summary attached) Estuarine ecosystems were evaluated on the basis of Individual large rivers, due to the availability of comprehensive sediment databases. Data associated with specific contaminated sites are included where available for additional information. Concentrations presented are mean total Chromium, except where indicated. Estuarine Ecosystems: **Newark Bay**: 137 mg/kg (Adams et al., 1998) **Lower Harbor** (includes Raritan and Sandy Hook Bays): 72 mg/kg (Adams et al., 1998) **Passaic River**: (Passaic River Study Area, 1996) a. **Point – No –Point Reach**: 357 mg/kg (81 samples) **Harrison Reach**: 455 mg/kg (180 samples) **Newark Reach**: 169 mg/kg (122 samples)

	Kearny Reach: 260 mg/kg (72 samples) 4. **Hackensack River** AlliedSignal Site: 1882 mg/kg b. Upstream reference for AlliedSignal: 305 mg/kg (Draft RI Report, Study Area 6 , 1999) Adjacent to Hackensack Meadowlands: 299 mg/kg (Eckenfelder, 1993) d. Hackensack Meadowlands (estuarine wetlands): 717 mg/kg (Eckenfelder, Inc. 1993) **Lower Delaware River:** a . 32 mg/kg (NJDEP 1995) (37 samples) b. 64 mg/kg (DRBC 1993) (11 samples) **Lower Raritan River** (expressed as range based on data from three contaminated sites, R.F. Weston, 1996): 32 – 494 mg/kg 7. **Atlantic Coastal Water** 67 mg/kg (NJDEP 1995) (2 samples) Urban/Terrestrial Ecosystems (historic fill from deposition of Chromite ore processing residue) Liberty State Park – Area 15 (expressed as range, BCM, 1993) Cr^{3+}: 10 – 6460 mg/kg Cr^{6+} : ND – 1400 mg/kg
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	Statewide ambient and enriched surface water and sediment concentrations of Chromium were compared to NJ Surface Water Quality Standards and sediment screening criteria, respectively, to assess the risk to aquatic receptors. Soil levels were compared to the

	NJDEP/SRP benchmark for Cr^{3+}, based on phytotoxicity. The hazard quotient (HQ) method was used to conduct a screening level risk assessment where: HQ = $\frac{\text{Estimated Environmental Concentration}}{\text{Benchmark Concentration}}$ This approach assumes that concentrations of the contaminant were representative of the exposure to biota in the four ecosystems evaluated. HQ values <1 indicate Chromium concentrations are at a level where adverse effected are not expected; HQ values>1 indicate the potential for adverse ecological effects.	
Risk Characterization		
Risk estimate(s) by population at risk	**STATEWIDE AMBIENT** (Note: Salinity measurements were not recorded in USGS 1998, therefore, for the purpose of this risk estimate, a distinction is not made between fresh and estuarine/marine surface water and sediments; freshwater benchmarks were used for both surface water and sediments) **Surface Water HQ range:** HQ = $\frac{1\ \mu g/l}{180\ \mu g/l}$ = **0 .006** to HQ = $\frac{7.3\ \mu g/l}{180\ \mu g/l}$ = **0.04** Sediment HQ Range (based on LEL) HQ = $\frac{10\ mg/kg}{26\ mg/kg}$ = **0 .39** to HQ = $\frac{50\ mg/kg}{26\ mg/kg}$ = **1.9**	Score 1 2

	2. TOTAL CHROMIUM ASSOCIATED WITH CONTAMINATED SITES AND/OR ENRICHED URBAN/INDUSTRIAL SETTINGS	1
	INLAND FRESH WATER:	2
	Surface Water: $HQ = \frac{4.9\ \mu g/l}{180\ \mu g/l} = 0.03$	
	Sediment: $HQ = \frac{89\ mg/kg}{26\ mg/kg} = 3.4$	2
	FRESH WATER WETLANDS	
	Sediment: $HQ = \frac{43.6\ mg/kg}{26\ mg/kg} = 1.7$	
	ESTUARINE ECOSYSTEMS	2
	1. **Newark Bay** $HQ = \frac{137\ mg/kg}{81\ mg/kg} = 1.7$	1
	2. **Lower Harbor**: $HQ = \frac{72\ mg/kg}{81\ mg/kg} = 0.8$	2
	3. **Passaic River**:	3
	Point-No Point Reach $HQ = \frac{357\ mg/kg}{81\ mg/kg} = 4.4$	2
	Harrison Reach: $HQ = \frac{455\ mg/kg}{81\ mg/kg} = 5.6$	2
	c. Newark Reach: $HQ = \frac{169\ mg/kg}{81\ mg/kg} = 2.0$	**4**
	d. Kearny Reach: $HQ = \frac{260\ mg/kg}{81\ mg/kg} = 3.2$	**4**

	4. **Hackensack River** AlliedSignal Site: $HQ = \frac{1882\ mg/kg}{81\ mg/kg} = 23$ Upstream reference for AlliedSignal: $HQ = \frac{305\ mg/kg}{81\ mg/kg} = 3.8$ River adjacent to Hackensack Meadowlands: $HQ = \frac{299\ mg/kg}{81\ mg/kg} = 3.7$ Hackensack Meadowlands (estuarine wetlands): $HQ = \frac{717\ mg/kg}{81\ mg/kg} = 8.9$ (area of historic fill containing Chromite ore processing residue) 5. **Lower Delaware River** a. $HQ = \frac{32\ mg/kg}{81\ mg/kg} = 0.4$ b. $HQ = \frac{64\ mg/kg}{81\ mg/kg} = 0.8$ 6. **Lower Raritan River** (based on maximum of range)) $HQ = \frac{494\ mg/kg}{81\ mg/kg} = 6.1$ 7. **Atlantic Coastal Water** $HQ = \frac{67\ mg/kg}{81\ mg/kg} = 0.8$	2 2 3 1 1 3
	URBAN/TERRESTRIAL ECOSYSTEMS (areas of historic fill	1

	containing Chromite ore processing residue) Liberty State Park – Area 15 Cr^{3+} (maximum concentration) $\frac{6460\ mg/kg}{200\ mg/kg} = 32$	 5
Assessment of severity/irreversibility	The following scale was used when assigning a score to the generated HQs: HQ Score <1 1 1-5 2 3 11-25 4 25+ 5	
Assessment of frequency of effect(s)	See attached table *Statewide Analysis of Threat*	
Size of population(s) and/or extent of the State/habitat affected (magnitude)	See attached table *Statewide Analysis of Threat*	
	Total	
Assessment of uncertainties in this assessment (H,M,L) and brief description	There is moderate-high uncertainty with the freshwater and terrestrial portions of this assessment due to limited sediment and surface water data availability, lack of comprehensive database for management of contaminated site data, and limited data for speciated Chromium. There is lower uncertainty associated with the estuarine portion of this assessment due to availability of comprehensive data sets from regulatory agencies (e.g., USEPA, NOAA, DRBC). There is particularly low uncertainty in the Passaic River due to multiple phases of the Passaic River Study, which has comprehensively characterized sediments downstream of the Dundee Dam.	
Potential for additional data to result in a significant future change in this risk estimate (H,M,L) and brief description. (Data Gaps; highlight significant data needs)	Additional data and data management strategies for environmentally sensitive areas in the State which are affected by historic fill containing Chromite ore processing residues are needed to better characterize risk from this threat. An ecotoxicologically-based soil benchmark for Cr^{6+} would facilitate risk estimations for this contaminant. Data from the Upper Delaware watershed are limited.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, -, =, = where + is improvement), and brief description.	The potential for significant future change in the underlying risk from total Chromium is rated (0). While long term improvement is expected due to source controls and remedial actions at contaminated sites, risk is expected to remain stable for a 5-10 year timeframe, due to technical and administrative complexities associated with remedial investigations and remedial actions, especially in areas enriched by diffuse anthropogenic sources and historic fill.	
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L: The potential for catastrophic impacts to NJ's ecosystems is considered to be low, based on the regulations in place to control contaminant discharges and required clean-ups, and current knowledge of the ecotoxicology of Chromium compounds.	

Link to other Work Groups (e.g., socioeconomic impacts)	Potential socioeconomic impacts of Chromium contamination include costs associated with source controls, contaminated site remediations, and natural resources damage assessments.
Extent to which threat is currently regulated	Control of chromium discharges and the remediation of Chromium-contaminated hazardous waste sites are regulated under the Industrial Site Recovery Act (ISRA), Spill Compensation and Control Act, Solid Waste Management Act (SWMA), Water Pollution Control Act (WPCA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended by Superfund Amendments and Reauthorization Act of 2986 (CERCLA) and the Hazardous Site Discharge Remediation Act.
Barriers to restoration	Presence of historic fill containing Chromite ore processing residues; technical and economic complexities associated with remedial activities.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	H: Chromite ore processing, electroplating, metal finishing, production of stainless and heat-resistant steels, production refractory products such as bricks and mortars, pigment production, leather tanning, textile manufacturing
Small business industry	H: Electroplating, metal finishing, publicly-owned waste treatment plants
Transportation	L
Residential	L
Agriculture	L
Recreation	L
Resource extraction	H: Chromite ore extraction/processing
Government	L
Natural sources/processes	M: natural weathering mobilizes 32,000 tons/year
Orphan contaminated sites	
Diffuse Sources	
Sediment sinks	H: in areas of known contaminated waste sites and/or urban/industrial areas
Soil sinks	H: in areas of chromium-contaminated fill; chromium in phosphates used as fertilizers
Non-local air sources incl. Deposition	H: Production and combustion of fossil fuels, smelting and refining of nonferrous base metals; major atmospheric emissions from chromium alloy and metal-producing industries. Lesser amounts are from coal combustion, municipal incinerators, cement production and cooling towers.
Biota sinks	L: little evidence of food chain biomagnification

Summary Statement:

Total Chromium levels are typically elevated in environmental media in the vicinities of electroplating, metal finishing, and tanning industries, as well as publicly owned domestic wastewater treatment plants. It is commonly found in two valence states in natural systems: trivalent Chromium, the dominant form, and hexavalent Chromium. Hexavalent

Issue: Chromium
Author: Hamill
Version: 04/06/00

Chromium is present at very low levels, since it is a strong oxidizer and readily reduced to the trivalent form. Toxicity to aquatic wildlife and terrestrial plants is attributable to both forms of Chromium.

Risk is characterized for fresh surface water, sediments and wetlands, estuarine/marine surface water and sediments, and soils, by comparing available media concentrations with ecotoxicologically-based benchmark values, generating a hazard quotient. A scale with five ranges of hazard quotients is used to quantitatively assign a Severity score between 1 and 5. Scores for Frequency and Magnitude were determined qualitatively, based on best professional judgement regarding rate of total Chromium input into the various ecosystems and percent of the specific ecosystem impacted Statewide, respectively. The Statewide Analysis of Threats indicates elevated scores for inland fresh water and wetlands, marine/estuarine ecosystems, and urban/industrial soils. The average statewide score is 9.6
Statewide Analysis of Threat Threat = Total Chromium

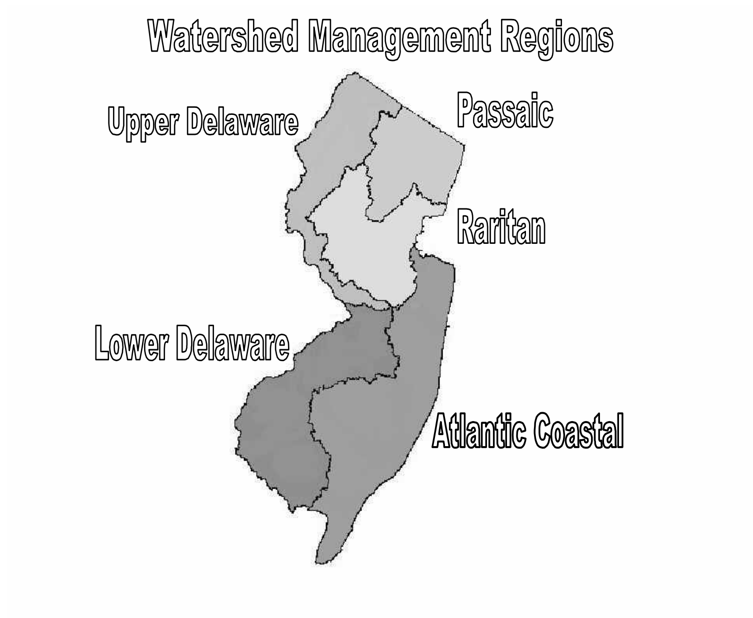
Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	3	2	18
Marine Waters	4	2	2	16
Wetlands	3	2	2	12
Forests	1	1	1	1
Grasslands	1	1	1	1
			Total Score	48
			Average Score (Total ÷ 5)	9.6

Issue: Chromium
Author: Hamill
Version: 04/06/00

Risk by Watershed Management Region

THREAT = Chromium	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L	NA	L	L	L
Passaic	M-H	H	H	L	L
Raritan	M	M	M	L	L
Atlantic	L	L	L	L	L
Lower Delaware	L	L	L	L	L
Region/Watershed (secondary)					
Urban	M-H	M-H	M-H	NA	NA
Suburban	L	L	L	L	L
Rural	L	L	L	L	L

H=high, M=medium, L=low, NA = not applicable



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Issue: Copper
Author: Tucker
Version: 03/11/00

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	**Findings**
Hazard Identification	
Stressor	**Copper**
Description of stressor	Soluble copper salts are potent bactericides and algaecides at low levels and toxic to humans and other animals in large doses. Yet copper is an essential trace element present in various metalloproteins required for the survival of plants and animals. Thus, there is some evidence, particularly for mammals, that copper deficiency may also be detrimental. Copper, atomic number 29, is the twentieth most abundant element present in the Earth's crust, at an average level of 68 parts per million. Since prehistoric times, human use of copper has meant that this non-ferrous metal is very widespread as an environmental contaminant. Copper may have been one of the earliest metals humans learned to use and work; its useful alloys gave rise to the technology we denote as the Bronze Age. Early metal production was instrumental in the development of human culture. Determination of copper concentrations in Greenland ice dated from seven millennia ago to the present show values exceeding natural levels, beginning about 2500 years ago. This early large-scale pollution of the atmosphere of the Northern Hemisphere is attributed to emissions from the crude, highly polluting smelting technologies used for copper production during Roman and medieval times, especially in Europe and China. (Hong, et al., 1996; Nriagu, 1996). An example of current era extensive pollution by copper is provided by results of mining and resource recovery activities in the Sudbury basin, Ontario, where it is estimated that mobilization of metals stored in soils and glacial overburden by surface runoff, groundwater drainage and wind re-working of tailings can sustain the high concentrations of Cu and Ni in many lakes for well over 1000 years. The combination of logging, smelting, fires and erosion resulted in an unusual anthropogenic ecosystem of denuded barren land with lifeless lakes, or a micro-desert. (Nriagu, et al., 1998) Elemental Copper and Copper Sulfate are pesticides currently and historically used as herbicides and fungicides in agriculture and for control of algae in aquatic pest management. **Copper Sulfate and its use as an aquatic pesticide**: Copper Sulfate ($CuSO_4$) takes on many forms but the commonly used form is Copper Sulfate pentahydrate. The empirical formula is $CuSO_4.5H_20$; the molecular weight is 249.69. Upon heating at 25^0C the compound loses its 5 moles of H_20 and becomes stable up to 65^0C. Solubility of copper sulfate pentahydrate is 31.6g/100cc at 0^oC and 203.3g/100^oC in water. Copper Sulfate is an odorless blue or green-white powder or crystalline solid. Copper Sulfate pentahydrate is a non-selective algicide that has been used to control algae in commercial, municipal, and irrigation waters systems of the United States

	Toxic properties of copper are taken advantage of in marine antifouling paints and in compounds, particularly Chromium, Arsenic and Copper (CCA) for pressure treating wood. Fouling is the successive development of marine organisms on immersed surfaces, a process which has heavy negative economic impacts. Several antifouling technologies, generally based on the leaching of biocides from painted surfaces, have been developed, but these biocides are toxic to the environment. The toxicity of several currently used antifoulilng paint components can be tested with specific enzymatic and metabolic capabilities of cell systems. (de Sousa, et al., 1998)
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	Biological integrity, biodiversity, habitat/ecosystem health, and ecosystem function were considered. $CuSO_4$ is and has been applied directly to surface waters for control of algae, macrophytes, insects, fish parasites, and sometimes fish themselves. Studies indicate that $CuSO_4$ is toxic to aquatic organisms, and that indiscriminate use can lead to reductions in populations of aquatic organisms, through direct toxicity or through the oxygen depletion that occurs when too much aquatic vegetation is killed at once. In previous years, the US Department of the Interior, Office of Endangered Species had determined that the use of $CuSO_4$ would pose a risk to several endangered species, such as Solano Grass, and several species of freshwater mussels. Long term use of $CuSO_4$ can lead to severe alga problems. Over a period of years, the copper carbonate buildup on the bottom of the pond actually will inhibit the growth of rooted bottom vegetation. Once rooted bottom vegetation cannot grow due to the buildup of copper carbonate on the bottom, the nutrients that this vegetation would have tied up are now available for excess algal growth. A study performed by Hansen and Stefan (1984) indicated that long-term ecological consequences of the addition of a toxic substance to a lake for the purpose of short-term relief from alga blooms report that 58 years of $CuSO_4$ use in many Minnesota lakes, while effective at times for temporary control of algae, have produced: dissolved oxygen depletions, increased internal nutrient cycling, occasional fish kills due to oxygen depletion, copper toxicity or both, copper accumulation in sediments, increased tolerance by some nuisance blue-green algae, and undesirable effects to fish and fish food community. They concluded that a short-term control of algae has been traded for long-term degradation of the lakes. Because Copper is differentially toxic to various types of organisms, poisoning microorganisms and algae, and some aquatic animals more readily than other organisms, and because it has become very widespread due to anthropogenic activities, it is advisable to consider carefully the overall effects of this metal on biological integrity and ecosystem function. Copper's low toxicity to humans may inure us to its potential ecosystem effects. Moreover, in the environment, rarely does contamination by copper occur alone; mining, hazardous waste sites, smelters, industrial emissions usually emit complex mixtures of contaminants. Separating effects of copper from other associated contaminants thus becomes more difficult. Uses of copper to counteract algal buildups resulting from high nutrient inputs, in antifouling paints or in pressure treatments for wood used in docks or for bulkheading, seem especially likely to disturb aquatic ecosystem function, perhaps in some cases even threatening biodiversity and habitat integrity in ponds, lakes, and in estuarine environments with low flushing rates.
Key impacts selected (critical ecological effects)	Biological integrity, biodiversity and habitat health: $CuSO_4$ is very toxic to fish food organisms, and highly toxic to fish, amphibians and crustaceans. Chronic and other effects are as follows: fish- growth, mortality, and

	physiological effects; amphibians-developmental, growth, and mortality; crustaceans - mortality. When $CuSO_4$ treatments are applied for many years, copper accumulates in the sediments and thereby affects the habitat of bottom dwelling organisms (e.g., benthic macroinvertebrates).
Exposure Assessment	
Exposure routes and pathways considered: Copper in air, water, soil, and in the foodweb provides potential ecosystem exposures. Population(s)/ecosystem(s) exposed statewide Quantification of exposure levels statewide	$CuSO_4$ is toxic to aquatic organisms, either through direct toxicity via direct application to surface water, or through the oxygen depletion that occurs when too much aquatic vegetation is killed at once. Since copper is an element it will persist indefinitely. According to the Journal of American Water Works Association (1970), $CuSO_4$ applications to water such as ponds etc. are fixed by the bottom and the factors controlling the fixation varies (nature of clay minerals, clay content, organic matter, or the percentage of limestone present). Copper is bound, or absorbed, to organic materials, and to clay and mineral surfaces. The degree of adsorption to soils depends on the acidity or alkalinity of the soil. $CuSO_4$ is water-soluble so it is mobile in soil. However, due to its binding capacity (except in sandy soil) its leaching potential is low. Ecosystem exposures to copper have resulted from mining and industrial activities dating to prehistoric times. Currently, according to EPA data, copper is second only to zinc, in the amount released to the environment. Copper is sometimes intentionally applied to aquatic ecosystems for control of algal growth. Copper, as a component of pesticides, has also been extensively applied to soils and crops in New Jersey, although this use is probably less now than several decades ago. The use of $CuSO_4$ for temporary algae control can produce significant zooplankton mortality at doses far below those needed for algal control. Severe mortality of zooplankton could explain the common rebound of algae after a copper treatment. Trout, ornamental goldfish, and other sensitive fishes may be adversely affected in very soft water. In addition to natural levels of copper, anthropogenic activities have so increased levels in the environment that copper is ubiquitous, statewide. $CuSO_4$ is directly applied to impounded waters, lakes, ponds, reservoirs, and irrigation drainage conveyance systems. Direct application of $CuSO_4$ to such water may effect a significant reduction in populations of aquatic invertebrates, plants and fish.

New Jersey $CuSO_4$ Use

Year	Pounds Applied	# of Sites
1999=	121,323	345
1998=	126,931	359
1997=	110,415	338
1996=	120,063	87
1995=	195,937	277
1994=	109,071	231
1993=	135,893	199
1992=	241,000	37

Suspicion that before ~ 1990, contamination may have invalidated metal analysis prior to the introduction of clean metal technology for sampling and measurement, has led to distrust of 'historic' metal values generated. Subsequently there has been inadequate sampling to characterize copper levels in the State. Currently available water and sediment sampling data by State and Federal agencies and programs, including USGS, USEPA, NJDEP, and the Estuary Programs, however, indicate that ambient standards and guidelines are rarely exceeded or if so, not substantially.

	The following data, although spotty, may be representative of copper concentrations in various media at hazardous waste sites in New Jersey (although not necessarily copper contaminated sites):
	ECOSYSTEM: Wetlands / Fresh Water Bermed Area of Nellie's Pond, Conwed Bonded Fiber, Delanco, Riverside Township, Burlington Co., NJ Copper Conc.: 6.5 µg/L in surface water 118 mg/kg in sediment 314 mg/kg in wetland soil SITE HISTORY: The Conwed Facility is located on 53 acres, two-thirds of which consist of the former industrial area that manufactured bonded cellulose blankets. The remainder of the site consists of disturbed mixed hardwood forest, successional oldfield, former agricultural field, the 8.5 acre Nellie's Pond, and the bermed area of Nellie's Pond (freshwater wetland DOCUMENT REFERENCE: "Baseline Ecological Evaluation," ISFA Case No. 95418, for Conwed Bonded Fiber, Burlington Co., NJ, in the Revised Remedial Site Investigation Report, March 1999. Fort Dix, New Hanover Twp., Pemberton Twp., Plumstead Twp., & Manchester Twp., in Burlington and Ocean Counties. Water body: Hanover Lake Copper Conc. 18,760 mg/kg in Sediments (ave., 2 samples) DOCUMENT REFERENCE: November 1999 Draft Field Sampling Plan for the Hanover Lake Area, Fort Dix, NJ. Horseshoe Rd Superfund Site Copper Conc.: 260 - 906 mg/kg in Sediments Lucent Technology Copper Conc.: 95 mg/kg in Sediments Picatinny Arsenal; Green Pond Brook, Morris County Copper Conc.: 290 mg/kg in Sediments

	Surface Water HydroQual, in a 1989 report, estimated that there was 2185 kg/day mass input of copper to the New York Bight Apex. Two thirds came through the transect from the harbor (line from Rockaway Pt to Sandy Hook), and of that portion half came from wastewater effluent and the other half from run-off. ~27% came from barge input (no longer occurs), ~ 5 to 6 % from atmospheric transport, and a very small amount from coastal transport. Powers Farm, Jackson Twp., Ocean Co. South Branch of the Metedeconk Creek Copper Conc.: 792 µg/L (ave., 2 samples) in Surface water 64 mg/kg in sediment DOCUMENT REFERENCE: May 5, 1997 Remedial Investigation Report **Ambient Streams Monitoring Program:** Conc., µg/L — yrs. — Location 19.8 — 85-89 — Hackensack R. at Riverdale 47 — 75-79 — Elizabeth R. at Ursino Lake 31 — 80-84 — " " 37 — 75-79 — South Branch, Pennsauken Cr., Cherry Hill 29 — 75-79 — S.B., Big Timber Cr., at Blackwood Terrace 16 — 90-94 — " " 164 — 75-79 — Great Egg Harbor River at Folsom 15 — 90-94 — " " 34 — 75-79 — Great Egg Harbor River at Weymouth 42 — 80-84 — " " 64 — 75-79 — Delaware River at Montague 1.3 — 90-94 — " " Most other values measured in surface water were below 15 µg/L, and tended to be lowest in the yr. 90-94 period. In the Phase I metals sampling and analysis program for the New Jersey Component of the NY/NJ Harbor Estuary Program, with sampling on at least 12 occasions, Copper values for Raritan Bay, Raritan River, Newark Bay, Hackensack River did not exceed 3 µg/L. In the Passaic River Copper reached 3.6 µg/L on one sampling date. (Water Quality Std., for brackish water = 5.6 µg/L)
	A report of 36 sampling stations in the 1998 USGS Water Quality Report for New Jersey gave values for copper, listed according to land use adjacent to the stream sampled:

	Agriculture: 1 - 4 µg/L With 5/7 detected Forest: 1- 2 µg/L 4/12 detected Urban 1 - 15 µg/L: 10/11 detected background 0/6 detected (at < 1 µg/L) **Quality Criteria** Surface water criteria, for copper, depends on hardness of the water, measured as $CaCO_3$. The equations for acute and chronic criteria are: Acute: = $e^{(0.9422\{\ln \text{hardness}\}-1.464)} x0.960$ Chronic:= $e^{(0.8545\{\ln \text{hardness}\}-1.465)} x0.960$ Karen Schaffer, of NJDEP's Division of Science, Research, and Technology, has prepared a Microsoft Excel Program which calculates criteria based on the above equations. As examples, the following values for hardness, give criteria values as listed: Hardness (mg/L $CaCO_3$) — Acute Criteria (µg/L) — Chronic Criteria (µg/L) 50 — 9 — 6 100 — 17 — 11 120 — 20 — 13 Most surface waters in New Jersey have hardness less than 100 mg/L As an indication of the greater sensitivity of many aquatic organisms to copper, the EPA human health criterion for copper is 1,300 µg/L. Soils A report of results of analysis of 67 samples of soil in urban areas of the Piedmont region of New Jersey listed a concentration average for copper of 38.7 mg/kg, a median of 29.5 mg/kg. The maximum concentration of any sample was 139 mg/kg. Screening benchmark for the toxicity of copper to earthworms is 50 mg/kg (Efroymson et al., 1997). **Sediments:** USEPA reported from a National Sediment Sampling Project that Copper was found in 192 of New Jersey stations tested, the highest number of Tier II (adverse effects to aquatic organisms possible but infrequent) stations for any of the chemicals tested. (National Sediment Inventory)

	Adams et al. (1998) estimated that 32 % of the sediments in the Newark Bay area exceeded the Effect Range-Median (ERM) value of 270 mg/kg; and the average copper concentration was 227 mg/kg. Divalent metals, such as copper, are typically associated with acid-volatile sulfide (AVS). These metals have sulfide solubility smaller than that of iron sulfide, making them less bioavailable as long as the AVS molar concentration (reservoir of sulfide anions in anoxic sediment) exceeds the sum of the molar concentrations of the simultaneously extracted metals. (EPA - Nat. Sed. Inven.)
Specific population(s) at increased risk	While soil organisms may be at risk at some industrial or hazardous waste sites, such contamination is likely to be quite localized. Aquatic populations of plants and animals, both freshwater and estuarine, are most likely to be at increased risk due to copper contamination and to the use of copper as an aquatic algicide. The use of $CuSO_4$ for temporary alga control can produce significant zooplankton mortality at doses far below those needed for algal control. Severe mortality of zooplankton could explain the common rebound of algae after a copper treatment. Trout, ornamental goldfish, and other sensitive fishes may be adversely affected in very soft water.
Quantification of exposure levels to population(s) at increased risk	An estimated 8,295,000 pounds of active ingredient are used annually in the United States (1986, Guidance for the Reregistration of Pesticide Products Containing Copper sulfate. From the data cited above, copper concentrations in sediment and soil at specific hazardous waste or industrial sites may exceed standards or guidelines, but there is no indication that ambient levels, apart from such specific sites, are above guidelines for ecological harm. Moreover, data availability for the State as a whole is probably not adequate to justify quantification with any degree of confidence.
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	In NJ, the use, amount of sites using $CuSO_4$, and the total amount of $CuSO_4$ used, has been on the rise since 1992. Due to a lack of data management in previous years (QA/QC), some data gaps occur. Accurate data management was implemented in 1999. Given the caveat above, regarding inadequacy of data Statewide, as well as the indication that, in general, guidelines, standards, or benchmarks are not exceeded, a quantitative assessment may not be justified. Thus, qualitatively, for ambient soil, sediments, and surface water values, **HQ** is less than 1, where HQ, the hazard quotient is given by the environmental concentration divided by benchmark concentrations. **HQ** exceed 1 at specific sites, for soil and/or sediments, as indicated by examples such as Horseshoe Rd and Picatinny Arsenal.

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Risk estimate(s) by population at risk	For individual aquatic systems. $CuSO_4$ is highly toxic to fish and aquatic invertebrates. $CuSO_4$ has been continuously used in years past and is widely and commonly used, today. According to Singleton and Guthrie (1977), bioconcentration and biomagnification of copper can occur in the food chain. Over a period of years of continued use, copper carbonate can accumulate in sediments of treated water bodies on the bottom of the pond. All species accumulate copper from the medium. In large concentrations, copper can disrupt the equilibrium between certain biota and their environment, thus interfering with naturally existing food webs. The contribution of waterborne copper to tissue burdens increase as water concentrations rise. Copper accumulation in fish gills increase with increasing concentrations of free copper in solution, increasing dissolved organic carbon and decreasing pH and alkalinity. For Statewide ambient conditions; surface water, sediments and soils. (Individual sites should be evaluated separately)
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	Copper is widespread in the environment, as a result of human activity, and will remain so for the foreseeable future; however evidence does not exist of severe ecological effects. The use of $CuSO_4$ dates back to the early 1900's. However, the limited data EPA held in 1986 did not indicate that an unreasonable hazard to non-target aquatic organisms existed. **SCORE = 2-3**
Assessment of frequency of effect(s): 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	$CuSO_4$ was the first chemical to be used for algae control, and has been applied to surface water since the early 1900's. This practice continues today. In New Jersey, this practice seems to increase on a yearly basis. This is due to the increase of aquatic sites permitted for aquatic pesticide applications. While sub-chronic effects may be very frequent due to the ubiquity of copper in the environment; however, as noted above, no evidence that substantial environmental effects result. **Score = 3**
Size of population(s) and/or Extent of the State/habitat	Copper is ubiquitous in the state; mostly aquatic systems are impacted by copper concentrations. There are

affected (impacted): 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted		750(+) private lakes in New Jersey (NJ). Approximately 600(+) of these are treated with aquatic pesticides, including $CuSO_4$. **Score = 2**
		Total 15 (12-18)
Assessment of uncertainties in this assessment (H,M,L) and brief description		H: Rate and extent of copper accumulations in fish tissues are extremely variable between species and are further modified by abiotic and biological variables. Historic data suspect before clean sampling and laboratory techniques instituted in the early 1990s. Inadequate data, on a Statewide basis, since then make assessment uncertainty high.
Potential for additional data o result in a significant future change in this risk estimate (H,M,L) and brief description. (Data Gaps; highlight significant data needs)	M: The effect of $CuSO_4$ treatments on the biology of a water body should be more thoroughly considered. Estimates of oxygen depletion should be made before treatment. Nutrient levels should be monitored and periodic surveys of benthic macroinvertebrates and fish should be made. Levels of Cu in sediment are not well characterized in treated water bodies. Alternatives for algal control, including nutrient limitations should be considered before $CuSO_4$ is used. Numerous and disparate copper criteria are proposed for protecting aquatic life (USGS, 1997) but they do not adequately protect sensitive species of plants and animals. Other research areas that merit additional effort include biomarkers for early copper stress; copper interactions with interrelated trace elements in cases of deficiency and excess copper; copper status effects on disease resistance, cancer, mutagenicity and birth effects; mechanisms of copper tolerance or acclimatization; and chemical speciation of copper, including measurement of flux rates of ionic copper from metallic copper. This type of data is needed to complete an evaluation of the hazards to non-target aquatic life by $CuSO_4$. Although Statewide data is inadequate, the data that does exist does not indicate an environmentally significant problem for this metal. Moreover, the trend data available, although meager, imply that copper concentrations are decreasing in surface water. Thus, additional data probably will not change the risk assessment.	
Potential for future changes in the underlying risk from this	**(+)** The effects of continuous $CuSO_4$ usage over a period of time have shown to have some detrimental effects to waterbody use and ecology. Some of these negative effects appear to be reversible. A lasting negative effect is the high cumulative cost compared to the temporary benefits from the use of $CuSO_4$, through long-term chemical dependency. Cleanup of specific contaminated sites (as contrasted to ambient conditions)	

stressor (+++, ++, +, 0, −, =, ≡ where + is improvement), and brief description.	has potential for improving risk. Ambient concentrations, although not a demonstrated hazard, may be causing sub-chronic stress; thus downward trends will help. Corrosion control, reducing leaching from plumbing may be one of the most promising strategies.
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	(L) Catastrophic impacts unlikely since there are no copper mines or smelters in NJ.
Link to other Work Groups (e.g., socioeconomic impacts)	Copper, a required micronutrient, has, at high levels demonstrated human health effects. $CuSO_4$ can be corrosive to the skin causing burning. It is also a skin sensitizer and can cause allergic reactions; skin contact may result in itching or eczema. Eye contact can cause conjunctivitis. Chronic exposure at high levels may lead to anemia and liver disease. $CuSO_4$ does bioaccumulate in the liver, brain, heart, kidney and muscles. Corrosion of copper plumbing has major economic impacts; thus corrosion control a big plus, both environmentally and economically. Although there are more effective products on the market, the use of $CuSO_4$ is as common as if was in the early 1900's. The two reasons for this are: cost and ease of application.
Extent to which threat is currently regulated or managed	Corrosion control now widespread (Pb, more of a threat). The use of $CuSO_4$ was not regulated in New Jersey (NJ) until 1989. Since then, the use of $CuSO_4$ is permitted through the NJ Pesticide Control Program (PCP).
Barriers to restoration	There are chlelated copper products on the market that are used for algae control. These products are less toxic to fish and aquatic invertebrates, and can cause less damage to the natural balance of a water body. Due to their expensive cost, $CuSO_4$ is the product of choice.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	(H) Electronics, Electrical industries; water purveyors (indirect, as a result of leaching from copper plumbing)
Small business industry	(H) Aquatic Pesticide Applicator Businesses are the main source of this stressor.
Transportation	(M) Copper has various uses in vehicles

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Residential	(H) Leaching from plumbing , use of CCA treated lumber, some homeowners and farmers apply $CuSO_4$ to their own ponds. Lake Associations are responsible for approving treatments (by pesticide applicators) of private lakes in the State.
Agriculture	(H) Copper in pesticides and fertilizers
Recreation	(H) Use of pesticides on golf courses
Resource extraction	(NA) (high in states with mining or smelting)
Government	(M) Some governmental agencies directly apply $CuSO_4$ to the government owned waterbodies.
Natural sources/processes	(H) Copper a common element in earth's crust
Orphan contaminated sites	(H) Probably very likely
Diffuse Sources	
Sediment sinks	(M) Likely, although extant data show only isolated very high values
Soil sinks	(M) Localized; possible agricultural run-off.
Non-local air sources incl. deposition	(M) Copper, as with other metals and organics is widely transported
Biota sinks	(M) Copper uptake is regulated in higher animals, plants may be a sink

Summary Statement: Copper Sulfate ($CuSO_4$) is a pesticide historically (and currently) used for aquatic pest management. The fate of pesticides in the urban environment has been of interest due to considerations of human and environmental safety. Copper Sulfate pentahydrate is a nonselective algaecide that has been used to control algae in commercial, municipal, and irrigation waters systems of the United States since 1904. Copper Sulfate is and has been the most widely employed algicidal chemical. It had been registered by the USDA for use in potable waters prior to 1970 and then by the Environmental Protection Agency (EPA) when it was established. Copper inhibits algal photosynthesis and changes nitrogen metabolism. An excess of copper sulfate kills algae by causing an imbalance with other enzyme metal cofactors resulting in enzyme blockage. Direct application of copper pesticides may cause a significant reduction in populations of aquatic invertebrates, plants and fish through reduction of oxygen as well as acute toxicity.

Statewide Analysis of Threat

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Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	4	3	36
Marine Waters	3	3-4	2	21 (18-24)
Wetlands	2-3	3	2	15 (12-18)
Forests	1	2	1	2
Grasslands	2	2	2	8
			Total Score	82
			Average Score (total score ÷ 5)	16.4

Risk by Watershed Management Region

THREAT = Copper	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	M	NA	L	L	L
Passaic	M-H	M-H	M-H	L	L
Raritan	M-H	M-H	M-H	L	L
Atlantic	M-H	L	M	L	L
Lower Delaware	M	M	M	L	L
Region/Watershed (secondary)					
Urban	M-H	M-H	M-H	NA	NA
Suburban	M-H	M	M	L	L
Rural	M-H	M	M	L	L

H=high, M=medium, L=low;

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Author: P. Bovitz
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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	**Findings**
Hazard Identification	
Stressor	**Deer** (*Odocoileus virginianus*)
Description of stressor	White-tailed deer populations have the potential for rapid growth, particularly in areas of high quality habitat, and in the absence of predation or hunting. As illustrated by the George Reserve deer herd studies in Michigan (McCullough 1979, 1982), deer herds may double their size in as little as one year. As a result of lack of predation, reduced hunting in suburban areas, establishment of public parks that act as deer refuges, and habitat modifications, increased deer population densities have resulted in ecological and socioeconomic impacts (e.g. agricultural damage, deer/vehicle collisions, and public concern over the incidence of Lyme disease among humans and pets). Deer population levels in excess of biological carrying capacity (high population densities) are eventually detrimental to the deer herd itself, resulting in malnutrition and increased stress from a limited food supply, increased parasite load, increased prevalence of disease, lower body weight, and reduced reproduction. Other potential ecological impacts from overpopulation include changes in plant species diversity and abundance that in turn may affect the rate of vegetative succession, as well as secondary impacts on other species of wildlife resulting from changes in vegetation structure. Additional effects include the spread of Lyme disease by deer ticks (*Ixodes* sp.) (Deer are the primary host for adult *Ixodes scapularis*) carrying the spirochete (*Borrelia burgdorferi*). While white-tailed deer are not considered reservoirs of the actual spirochete, they do help to spread the ticks. Continued overpopulation of deer relative to biological carrying capacity and desired wildlife management goals threatens to further shift the composition of plant communities toward less palatable and woody species, as well as reducing breeding habitat for birds, mammals and possibly invertebrates utilizing understory habitat.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	**Biological Integrity** – Given the role that predators may play in helping to control deer populations, it is likely that the biological integrity of terrestrial systems in New Jersey has already been impacted by the historical extirpation of large carnivores from colonial times through the early 1900s.). This, in addition to other factors such as conversion of habitat from forest to early successional communities has resulted in increased deer populations that have further altered habitat. For example, some parks in the Northeast have recently supported one deer per two acres. In addition to other major factors such as diseases like the Chestnut blight, Dutch elm disease, gypsy moths, and the invasion of exotic plant species, it is likely that the populations of deer in many areas have contributed to altering New Jersey native vegetation communities relative to historical conditions. (???,missing reference? **Biodiversity** – White-tailed deer are selective browsers (Hofmann 1985, Putman 1988) that favor the growth of young woody vegetation, but also may forage extensively on herbaceous vegetation during summer months (McCaffery et al 1974). Deer have proven to be more than browsers of woody vegetation, especially in agricultural and suburban areas. They eat the most nutritious vegetation available. New Jersey's deer populations are heavily dependent on herbaceous vegetation in many areas of the State. Because of this, they may reduce the diversity of plant species present in forest communities, affect the relative abundance of woody and herbaceous vegetation species, and affect the nature and direction of plant succession in forest and edge habitats (reviewed in Waller and Alverson 1997, and Stromayer and Warren, 1997). For example, because deer

forage extensively on tree seedlings (Harlow and Downing 1970, Marquis 1974, Marquis 1981, Tilghman 1989), high deer densities have been shown to depress the regeneration of some hardwood species, favoring less palatable species such as American beech (*Fagus grandifolia*) (Waller and Alverson, 1997).

Deer may affect the relative abundance of plant species by affecting seedling recruitment of woody plants, and by direct grazing on herbaceous species, sometimes to the point of local extirpation of these species, including rare plants (Waller and Alverson, 1997). As a result, deer impacts on vegetative succession can result in development of alternate stable states in woody plant communities (Stromayer and Warren, 1997). For example, they cited a study by Little and Somes (1965) that concluded excessive deer browsing was eliminating white cedar (*Chymacypaeris thyoides*) regeneration from many swamps in the New Jersey Pinelands Region, where fires or clearcutting by humans had previously occurred. Deer can impact white cedar even at low population densities (per square mile of range), because they often concentrate in lowland areas during the winter period where they may forage preferentially on cedar.
In more suburban habitats, adverse effects of deer browsing are compounded by the invasion of woody and exotic herbaceous plant species (Waller and Alverson, 1997); in New Jersey these include garlic mustard (*Alliaria* sp.), Japanese honeysuckle (*Lonicera japonica*), and others.

Habitat/ecosystem health – Reductions in plant species diversity and vegetative cover within the herbaceous and shrub layers of forested habitats have resulted in a potential reduction of habitat for bird species breeding within these vegetative strata, and potential interactions with other species of mammals. Thus, McShea and Rappole (1992) and later Waller and Alverson (1997) suggested that white-tailed deer may act as "keystone species" whose impacts affect other trophic levels. Casey and Hein (1983) noted reduced avian diversity in areas with high deer density, and DeCalesta (1994) noted reduced abundance of intermediate-canopy bird species, and an overall reduction in avian species diversity in areas with high deer densities. McShea (1997) observed complex interactions between deer browsing, squirrel abundance and breeding bird populations; similar interactions were observed by Ostfeld et al (1996). High deer densities may also affect invertebrate abundance and distribution; Miller et al (1992) reported that high deer densities may depress populations of the Karner blue butterfly (*Lycaeides melissa samuelis*), an endangered species, in New Hampshire.

Ecosystem function – Increased herbivory by deer can cause a reduction in the amount of biomass present in the shrub layer, with a corresponding reduction of shading to the herbaceous layer, affecting species composition via seed germination and growth (Stromayer and Warren 1997). Corresponding changes in nutrient cycling associated with increased herbivory and defecation may result in less nitrogen stored in plant tissue, and more present in the soil in form readily available for leaching or runoff. This in turn could affect overall nutrient budgets and adjacent aquatic systems. While we are unaware of any documented studies supporting this possibility, it is an area potentially warranting additional research given the effects that have been noted of pet waste on coliform and nitrate levels on runoff quality in suburban watersheds.

Changes in plant community composition;
Secondary impacts on wildlife (e.g. reduced breeding bird diversity and abundance of understory species). These effects have been documented in the northeastern United States, but their extent in New Jersey is presently unknown. This suggests another potential research need.

Key impacts selected (critical ecological effects)	
Exposure Assessment Exposure routes and pathways considered	Ecosystems are affected by deer due to their activities (e.g., selective browsing) which is exacerbated by increased deer densities. Increased deer densities result from: ▪ Land use changes favoring increased forest fragmentation and edge habitat, as well as a mosaic of suburban development, woodlots and agricultural areas (also home gardens, lawns, and residential landscaping.) ▪ Reduction or elimination of predators in historical times. No predator species has been reduced in numbers or eliminated in modern times in NJ. Black bear and bobcat are occasional, opportunistic predators on deer and their numbers are increasing. Coyotes have become well established in NJ and elsewhere in the eastern US during the past 20 years. Coyote populations continue to increase in NJ and this species has been noted in all 21 NJ Counties. Coyotes can have an impact on young fawns and adult deer when there is deep and crusted snow. To date, coyotes have not had a significant impact on deer in NJ. Deer are a lesser component of a coyote's diet. In most areas of the country, rodents and other small mammals such as rabbits are an important part of a coyote's diet. ▪ Increased nutrient content of forage (e.g. fertilizing shrubs, etc. in yards) ▪ Reduction or elimination of hunting pressure or other means of population control due to local ordinances prohibiting hunting or firearm discharge. ▪ Local land use regulations that create low density housing patterns, green belts, and conservation areas that have inadvertently created deer refuges. ▪ Public acquisition of open space and subsequent prohibitions on hunting, resulting in establishment of deer refuges. ▪ Private landowner opposition to hunting or public access to land for hunting purposes. ▪ Hunter resistance to deer population reduction or harvest of antlerless deer. ▪ Declining hunter numbers and participation (lack of time). ▪ Declining hunter access to huntable private land. ▪ High hunting lease fees. ▪ State regulations that restrict hunting due to safety or other reasons (For example, the prohibition of bow hunting within 450 feet of a building.)
Population(s)/ecosystem(s) exposed statewide	Terrestrial ecosystems are exposed to risks resulting from overabundance statewide with the exception of urban areas. Vegetation impacts have not been studied extensively in New Jersey. It is known that impacts to upland forested areas in the Pinelands are probably minimal. However, adverse impacts to vegetation communities may be expected in areas with high deer densities (well in excess of the 20 individual/square mile figure where effects have been documented in the literature). These include counties with large areas of mixed suburban and rural land use, such as Somerset, Hunterdon, Burlington, Morris, and Mercer Counties. Geographically, the impacts can be expected to be greatest in the upper Delaware and Raritan watersheds, as well as portions of the lower Delaware watershed in Salem County. These correspond to deer management zones 5,7,8,10,11,12, 29, 41 and 63.

Quantification of exposure levels statewide	According to the New Jersey Division of Fish and Wildlife, goals of the 1999-2000 hunting season are to reduce deer populations in over 76% of the state's white-tailed deer range. New Jersey's deer are managed on a "deer management zone" basis. Most of the reduction goals are based on cultural carrying capacity concerns, not on biological carrying capacity limitations. Deer damage to agricultural crops and deer-human conflicts in suburban areas are the primary influences on deer management at this time. The 2000-2001 statewide goals are to reduce the deer populations on 74 % of the deer range, stabilize the population on 22 % of the range and allow for small increases on 4 % of the range. Specific impacts to plant communities statewide have not been quantified. However, McDonald (2000) indicated that once deer densities are sustained above 20 per square mile for several years, effects on the native plant community become noticeable. It is not known whether this applies to all ecosystems used by deer in New Jersey.
Specific population(s) at increased risk	Plant communities in forested areas, particularly in areas of high deer density (e.g. deciduous forested areas of the state within the above mentioned deer management zones). Rare herbaceous plant species could also be at risk in some areas due to grazing by deer in summer months. This is another potential research need. An inventory of potentially threatened populations might be undertaken by comparing the distribution of endangered/threatened plant species in the NJ Natural Heritage Program database with population density data for deer statewide.
Quantification of exposure levels to population(s) at increased risk	Specific quantitative studies of the extent of impacts to vegetation communities were not found. According to the Division of Fish and Wildlife, goals of the 2000-2001 hunting season were to reduce the deer herd in over 74% of its statewide range (undeveloped upland areas of NJ), implying that the problem is nearly statewide. Again, the deer population reductions are generally based on deer-human conflict and especially damage to commercial agriculture. Deer population objectives for undeveloped forested areas are based on biological carrying capacity and generally call for stabilization of the deer population. The impact of deer on vegetation is an important consideration for special management areas including State and County Parks, and National Wildlife Refuges.
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	None. See immediately preceding section.
Risk Characterization	
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)	**Score**

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Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure function hardly affected 1 - No detectable exposure	Note: Some authors have noted that effects may take decades if not hundreds of years to reverse. While a score of 3 could be argued, since the ecosystem remains intact, but structure and function can be affected, the threat is actually a 4 based on what is predicted to happen (in the next 5 years?? Timeline for NJCRP) if the state's deer herd is not further controlled in some areas. New Jersey is a very diverse state. The actual impact of deer on ecosystems within the State is unknown and is likely to vary from area to area. Deer densities also vary from area to area. Major deer management zones have average deer densities per square mile of habitat that range from under 20 to over 80 (pre-hunting season). Deer densities in some refuges and winter concentration areas can exceed 200 deer per square mile. The impact of deer on ecosystems should be determined and assessed by deer management zone, watershed or other definable area. Political subdivisions, especially counties, are not recommended for management purposes since land use, deer densities, habitat, soils, land ownership and other factors vary within counties. On a statewide basis, deer have little or no impact on marine and inland waters and urban ecosystems, these would be rated a "1". Paul, to get this more in line with the other templates, I would suggest a score of 3-4 or 3.5. This seems supportable based on the data presented.	3-4 terrestrial ecosystems 1 – aquatic and urban Average = 3
Assessment of frequency of effect(s) (list definition for each category, e.g. 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	If the figure of 20 deer per square mile can be used as a guide by which impacts to vegetation communities are expected, then deer overabundance is a potential problem in several terrestrial habitats statewide, particularly forested areas in the upper Delaware and Raritan watersheds, and portions of the lower Delaware watershed. However, according to the New Jersey Division of Fish, Game, and Wildlife, deer populations have exceeded 20 individuals per square mile in the Pinelands since the 1930s and many other areas of the state since the 1950s. Deer harvest levels in New Jersey, as in most states, are based on population management goals designed to reduce deer damage to agriculture and other deer-human conflicts (e.g. vehicle collisions). (Paul, it would seem that effects are often and continuing; I'm not sure that the data indicates that impacts are increasing only due to deer (e.g., sprawl is a factor).	4??

Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/ impacted 4- 25-50% of the State impacted 3- 10-25% of the State impacted 2- 5-10% of the State impacted 1- <5% of the State impacted	It is assumed that most terrestrial habitats frequented by deer are heavily affected, although little quantitative data exist on the frequency of effects. Paul, this score should reflect the area of the state showing impacts directly due to deer, since deer have not been shown to impact marine waters, and maybe not inland waters, this number should probably be lower. Does the deer adversely impact 100% of forests in the state? My guess is that this number should be around a 3 or 3.5. What do you think??	3
	Total	36
Assessment of uncertainties in this assessment (H,M,L) and brief description	L – changes to plant community and biology of the herd are well documented M – changes to nutrient budgets, ecosystem function and impacts to invertebrates or other wildlife species are less well documented	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	M – future population control efforts, if successful, could reduce populations back to levels that are satisfactory to meet management goals based largely upon socioeconomic impacts. However, even at those levels deer could still be having an impact on the forest under-story. It thus appears more research is needed to determine the extent to which harvest levels are protective of potential long term ecological impacts to plant communities. Data gaps/significant data needs – <u>Effects</u>: Secondary impacts of deer herbivory on populations of exotic plants, as well as populations of other species of wildlife such as breeding birds, small mammals, reptiles, amphibians and invertebrates in New Jersey. This needs to be documented for NJ. <u>Control</u>: Deer contraception or alternative control methods. (It is unlikely that a cost effective, “birth control” approach will be developed in the near future for free ranging deer. However, the Division’s Community Based Deer Management Program (CBDMP) has been successful (for example, Watchung Reservation) and was expanded in 2000.) Special area deer management programs have also been successful in deer population reduction on public lands. The Division has extended the deer hunting seasons, increased bag limits, instituted requirements to harvest antlerless deer first and made other regulations changes that are designed to reduce deer numbers. Predator reintroduction: It is extremely unlikely that wolves or cougars will ever be reintroduced in NJ due to lack of sufficient habitat area, and potential human conflicts. It is possible that reintroduction efforts elsewhere could result in wolves returning to NJ in the distant future. For example, there are efforts underway to reintroduce wolves in the Northeast, including northern Maine. Northwestern NJ was identified as potential habitat for an expanding wolf population. Conflicts with the human population could be anticipated.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	Direction of change depends upon the success of future population control efforts. ++ (with future control efforts being successful) = (with no future action)	
Potential for catastrophic impacts (H,M,L) and brief description	L – primarily if overabundance of deer resulted in some unforeseen disease outbreak affecting another species.	
Link to other Work Groups (e.g., socioeconomic impacts)	Socioeconomic impacts are of major importance: Agricultural damage, damage to homeowners, deer/vehicle collisions and Lyme Disease. Socioeconomic impacts may also be positive.	

	Thousands of people also enjoy hunting, photographing and seeing deer. Deer hunting generates an estimated 1.5 million recreation days annually and $100,000,000 in hunter expenditures.
Extent to which threat is currently regulated or otherwise managed	Intensive management of the state's deer herd is being undertaken; Major impacts are in areas where populations are not subject to hunting or other means of control sufficient to control deer populations to the point where adverse effects may occur. The Division's Fish and Game Council is authorized and required by N.J.S.A. 13:1B-29 et seq. to manage wildlife throughout the State of New Jersey as a renewable resource and to maximize the benefits derived from this resource, including the taking of game species and furbearers, while minimizing the negative impacts. The primary deer population control mechanism is sport hunting. There are six deer seasons. Deer hunting begins in early September in many areas and concludes at the end of January (mid-February in one zone). Many changes have been made in the deer management program in recent years in an effort to reduce deer numbers. Farmers may control deer that are damaging crops via special deer depredation permits throughout the year. The CBDMP, which provides for alternatives to sport hunting, is available to municipal and county governments, airports and the agricultural community. Experimental quality deer management programs have been implemented that would reduce deer numbers, increase the number of older age class males, create a more balanced buck to doe ratio, maintain a high level of harvest of adult does and provide other benefits.
Barriers to restoration	Regulations, public attitudes, private land ownership and/or present land use patterns (e.g. suburban areas) that prohibit hunting, physical and societal limitations to reestablishment of predators at historical levels, establishment of public and private deer refuges, or other means of population control. Technological or cost considerations relative to use of contraceptives Safe and cost efficient deer fertility control has yet to be developed for free ranging deer. Funding for alternative control methods is inadequate.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	L
Small business industry	L
Transportation	H – roadways cause increased fragmentation and create additional edge habitat favorable for deer. These areas in turn may act as an attractant to deer, where they are hit by vehicles. New Jersey's increasing human population has resulted in more cars being driven more miles, making deer collisions more frequent.
Residential	H – habitat fragmentation and conversion of farmland to residential development with landscape plantings results in major increases of favorable deer foraging habitat in areas where sufficient forested area remains to support deer herds. Creation of low density housing patterns in forested areas has the same effect. Site coverage for areas zoned for a house per three or more acres is low, and people plant gardens and landscaping that are very attractive to deer and may increase biological carrying capacity. Low-density housing patterns also inhibit hunting as a management tool. For example a single house can eliminate hunting on approximately 20 acres due to the prohibition on hunting within 450 feet of a building.
Agriculture	H – conversion of agricultural property to development (as above); crops are a food source for deer.
Recreation	L
Resource extraction	L
Government	H – ineffective management strategies allow deer to overpopulate in areas where hunting is not allowed or feasible. Municipalities have

	often prohibited hunting based on perceived safety concerns. The impact of zoning decisions on deer needs to be considered as well. There are areas (Zones 36 and 49) within the State where the NJ Division of Fish and Wildlife management strategy calls for elimination of deer. Management strategies also call for major deer population reductions in other developing areas (Zones 33 and 42) which are developing at a rapid rate. Public funding will be needed for CBDMP to succeed as an alternative deer population control approach.
Natural sources/processes	H – deer populations have steadily increased in the eastern United States since the 1940's, as agricultural land taken out of production has gradually reverted to young forest. Deer numbers have also increased as a result of restocking deer in some areas during the 1950's. Deer filled available habitat in the pinelands and northwestern NJ in the 1930s. Deer populations grew in many areas of central NJ in the 1950s and 1960s. Deer populations expanded in southwestern NJ in the 1970s and 1980s. The last area of NJ to be populated with deer included portions of the inner-coastal plain in northern Burlington and western Monmouth Counties since the mid-1980s. New Jersey's minimum deer population has fluctuated around 175,000 since 1985. The deer population peak probably occurred in 1995 at 204,500 (summer) and was last estimated at 177,400 in 1998 (summer). Problems in managing deer in NJ suburban areas became evident in the mid-1970s and increased with human encroachment of rural lands through the 1990s.
Orphan contaminated sites	L
Diffuse Sources	
Sediment sinks	L
Soil sinks	L
Non-local air sources incl. deposition	L
Biota sinks	L

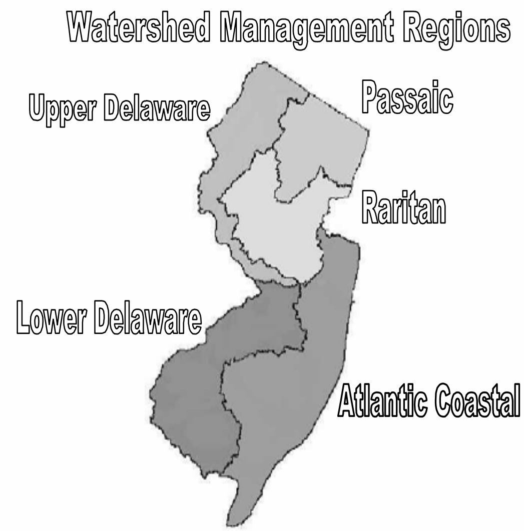
Summary Statement:

White-tailed deer are a native species whose population densities have increased locally to the point of potentially damaging native ecosystems. The reasons for deer overabundance are related to changes in land use resulting in conversion of agricultural and forested lands to suburban habitats (and low density housing patterns), historical extirpation of predators, (creation of deer refuges, reduced hunter access to deer, declining hunter numbers) and the inability of hunting (or other control) programs to control deer abundance in townships or on properties where hunting is not allowed (local ordinances which ban or restrict hunting). Overabundance of deer is known to cause changes in the structure and function of plant communities, since deer may eliminate or reduce understory and herbaceous layer plants, including rare and endangered species. As a result, the abundance of other species such as birds that breed in the understory may be affected, and the invasion of exotic species that are less palatable to deer may be facilitated. Because deer impacts may take decades to reverse, the severity of the threat has been rated as a "3.5". While the extent of deer impacts on vegetation communities in particular is likely to be statewide with respect to deciduous forested areas, it has not been studied. Based upon deer densities, the extent of biological impacts are likely to be greatest in management zones 5, 7, 8, 10, 11, 12 and 41, which cover much of Warren and Hunterdon Counties, and zones 29 and 63 in Salem County. In these areas deer densities were estimated in 1998 to be greater than 50 individuals per square mile, and in some cases (e.g. zones 10 and 11) over 70 individuals per square mile. The areas of the state with the highest deer densities appear to be within the Upper Delaware and Raritan watersheds, as well as portions of the lower Delaware watershed.

Statewide Analysis of Threat Threat = Native Animals – DEER

Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score

Inland Waters	NA	NA	NA	NA
Marine Waters	NA	NA	NA	NA
Wetlands	3.5	4	4	56
Forests	3.5	45	5	70
Grasslands	3.5	45	3	42



Total Score	168
Average Score (Total ÷ 5)	33.6

Risk by Watershed Management Region

THREAT = DEER	*ECOSYSTEM*				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	NA	NA	H	H	M
Passaic	NA	NA	H	H	M
Raritan	NA	NA	H	H	M
Atlantic	NA	NA	H	H	M
Lower Delaware	NA	NA	H	H	M
Region/Watershed (secondary)					
Urban	NA	NA	NA	NA	NA
Suburban	NA	NA	H	H	M
Rural	NA	NA	H	H	M

H=high, M=medium, L=low, NA = not applicable

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Statewide Analysis of Threat Threat = Native Animals: DEER

Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	NA	NA	NA	0
Marine Waters	NA	NA	NA	0
Wetlands	3	5	5	75
Forests	3	4	5	60
Grasslands	3	5	5	75
			Total Score	210
			Average Score (Total ÷ 5)	42

Risk by Watershed Management Region

THREAT = DEER	*ECOSYSTEM*				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	NA	NA	H	H	M
Passaic	NA	NA	M	M	M
Raritan	NA	NA	H	H	M
Atlantic	NA	NA	M	M	M
Lower Delaware	NA	NA	H	H	M
Region/Watershed (secondary)					
Urban	NA	NA	NA	NA	NA
Suburban	NA	NA	H	H	M
Rural	NA	NA	H	H	M

H=high, M=medium, L=low, NA = not applicable

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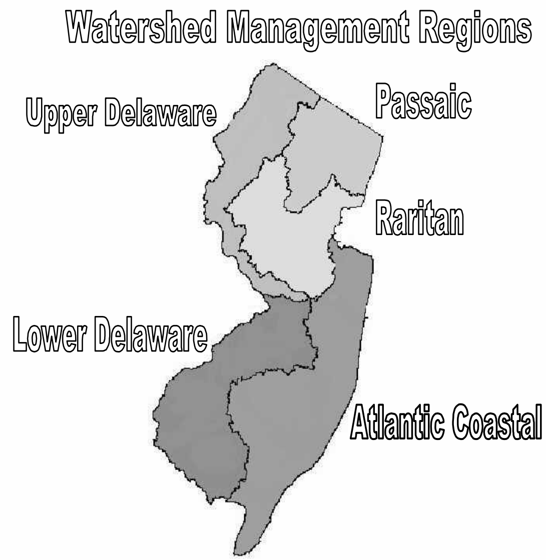

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Issue: Dermo Parasite in Oysters
Author: Mary Downes-Gastrich
Version: 05/00

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Dermo Parasite in Oysters**
Description of stressor	*Perkinsus marinus (=Dermocystidium marinum, =Labyrinthomyxa marina)* is a water-borne parasitic protozoan (Apicomplexa) and resembles the Dinoflagellida (Fisheries and Oceans Canada 1999; Goggin and Barker 1993; Siddall et al.) 1997). The parasite was discovered in 1990 (Ford et al.) 1996) in the host species, the Eastern oyster, *Crassostrea virginica* (Fisheries and Oceans Canada, 1999) in several locations on the New Jersey side of the Delaware Bay (Ford et al.) 1996). Dermo has been known since the late 1940s where it infected oysters in the Gulf of Mexico. ***P. marinus* causes mortalities in oysters from the western Gulf of Mexico to southern Maine on the east coast of North America** (Ford & Tripp 1996 and others). In the mid-1950s, *P. marinus* was found in Delaware Bay after the importation of infected seed oysters from lower Chesapeake Bay, but it disappeared when imports were embargoed (Ford &Haskin 1982; Ford & Tripp 1996). In New Jersey, an epizootic of *Perkinsus* recurred in oysters in Delaware Bay, beginning in 1990, and was associated with abnormally high winter temperatures (Ford & Tripp 1996; Ford 1992).
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	**Biological Integrity:** This parasite adversely affects the abundance and productivity of *C. virginica* **Effects of Disease on Oyster Metabolism** **Growth** *P. marinus* reduces both shell and soft tissue growth in oysters. Quantitative studies of oysters from Louisiana have shown that oysters with light infections deposited new shell at a slower growth rate than uninfected oysters for the preceding 2 months while those with heavy parasitism failed to add new shells for the previous 5 months (Menzel and Hopkins 1955). Soft oyster tissue is affected by parasitism (Ray et al.1953) and the oyster condition index (ratio of soft tissue dry weight to internal shell volume) was negatively correlated with the parasite intensity (Crosby and Roberts 1990; Ford & Tripp 1996). Physiological Functions: Adductor muscle in oyster is impaired with infection (Ford & Tripp 1996). Infected oysters failed to open and feed (Hewatt 1952). **Biochemical Composition:** Glycogen is depleted in oysters with advanced infections (Stein and Mackin 1957), amino acids and proteins are altered by infection (Ford & Tripp 1996).
	Reproduction:

	Gametogenic development in oysters is impaired after infections become advanced (Dittman 1993; Ford & Tripp 1996). **Cause of Death:** Extensive tissue lysis (disintegration) and occlusion of hemolymph vessels causes death in infected oysters (Mackin 1951, Ray 1954, Perkins 1976). **Gross observations**: Infected oysters may have a pale appearance to the digestive gland, reductions in condition index (above), severe emaciation, gaping, shrinkage of the mantle away from the outer edge of the shell, reduced gonadal development (above) and of decrease in growth (above) (Fisheries and Oceans Canada 1999).
Key impacts selected (critical ecological effects)	Oyster mortalities Reduction in soft tissue and shell growth Altered biochemical composition Impaired reproduction
Exposure Assessment	
Exposure routes and pathways considered	**Transmission of parasite**: All stages of *P. marinus* appear infective are distributed in water and oysters are exposed through feeding (Ford & Tripp 1996; Mackin 1951; Perkins 1988; Goggin et al.) 1989) and/or exposures from release of parasites from disintegrating dead oysters (Andrews and Hewatt 1957) and/or distributed by other animals feeding on the tissues of dead oysters (Hoese 1963) and possibly, vectors such as snails that may transmit it to oysters (White et al.) 1987, 1989). **Portal of Entry**: Infections may be initiated when *P. marinus* is ingested by the oysters and crosses the epithelium (protective lining) of the stomach or intestine (Ford & Tripp 1996; Perkins 1976). Parasites can be ingested and transported through the gill or mantle epithelium layer by the oyster phagocytes (=eating cells) (Ford & Tripp 1996; Mackin 1951; Mackin and Boswell 1956; Perkins 1976, others).
Population(s)/ecosystem(s) exposed statewide	Eastern oyster, *Crassostrea virginica,* in the Delaware Estuary (WMA #17 – oyster beds)(Ford et al.) 1996) and oysters on the Atlantic coast are also affected (Ford, pers. comm.). Dermo disease spread over most of the New Jersey side of the Delaware Bay with heavy losses of both seed and planted oysters (Ford et al.) 1996).
Quantification of exposure levels statewide	**Prevalence levels and mortality rates**: The prevalence of *P. marinus* infections was less than 30% and typical of enzootic areas in the Delaware in the mid-1950s, when the parasite was introduced, and no mortalities were reported (Christensen 1956). Younger oysters are less likely to become infected and have lower mortality rates than older oysters (Mackin 1951; Ray 1954; Andrews and Hewatt 1957; Ford & Tripp 1996). **Epizootic/enzootic periodicity:** No studies in New Jersey.
	Environmental Influences: **Temperature:** *P. marinus* infects, spreads and kills oysters most rapidly at temperatures above 25^0 C (Andrews 1965; Hewatt &

	Andrews 1955; Fisher et al.) 1992; Ford & Tripp 1996). Prevalence and intensity of the parasite decreases over winter and early spring (Ragone Calvo & Burreson 1994). **Salinity:** Low salinity reduces the prevalence of *P. marinus* (Mackin 1951, 1956; Christensen 1956; Andrews and Hewatt 1957, others) and the parasite is intolerant of salinities below 8-9 ppt in the field (Mackin 1956). For a full epizootic, a 12 ppt is usually required (Ford & Tripp 1996). However, MSX is more tolerant of low salinity than this and can withstand salinities as low as 3 ppt (Ford, pers. comm.). **Biological Factors**: Parasitism by the sucking snail, *Boonea impressa,* increases the severity of the disease in previously infected oysters (White et al.) 1987; Wilson et al.) 1988); **Environmental Factors:** The distribution of *P. marinus* is not linked to environmental contaminants (Ford, pers. comm.)	
Specific population(s) at increased risk	Eastern oyster, *Crassostrea virginica,* in the Delaware Estuary and on the Atlantic coast (and experimentally infected *C. gigas). C. gigas* is not at risk because it does not develop the disease, and it does not constitute a population in NJ or anywhere nearby (Ford, pers. comm.).	
Quantification of exposure levels to population(s) at increased risk	Epizootics in Delaware Bay in the late 1980s and early 1990s resulted in the apparent movement of infective stages over several miles in a single season (as reported in Ford & Tripp 1996).	
Dose/Impact-Response Assessment		
Quantitative impact-assessment employed	Studies on temperature, salinity, and biological influences on infection rates – see "quantification of exposure levels statewide" above. MSX disease-resistant strains of oysters survived better than unselected strains when *P. marinus* was inoculated into the oysters – at doses of up to 10^4 *P. marinus* cells per oyster (Valiulis 1973). However, this result was not validated in the 1990 epizootic and there is no link between MSX and dermo resistance (Ford, pers. comm.).	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score

Assessment of severity/irreversibility Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	Resistance: Few studies report resistant strains of oysters. However, MSX disease-resistant strains of oysters survived better than unselected strains when *P. marinus* was inoculated into the oysters – at doses of up to 10^4 *P. marinus* cells per oyster (Valiulis 1973). There may be heritable resistance to Dermo because oysters from NJ and Maine, which had undergone little or no selective pressure, developed significantly heavier infections than oysters from TX and VA, where populations were parasitized for more than 40 yrs (Bushek 1994; reported in Ford & Tripp 1996). In the Delaware Bay, infective stages are present throughout the warm months (May – October) (Andrews and Hewatt 1957; Ford & Tripp 1996). In the Chesapeake Bay studies, the cycle of infection occurs earlier and more frequently each year that oysters remain exposed (Andrews 1967).	**3**
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	See discussion in box above. The catastrophic effects of Dermo have already occurred.	**3**

Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	Observed in specific locations in NJ waters of the Delaware Bay. However, the Eastern oyster, *Crassostrea virginica* natural beds or reefs (seed beds) cover much of the upper Delaware Bay (Delaware Bay in **WMA #17, #16)** and the Atlantic coast produce the seed oysters essential for the oyster industry; in the Delaware Estuary, oysters grow from the Delaware Bay entrance to Bombay Hook on the Delaware side and to just below Artificial Island on the New Jersey side, a salinity range of about 30 ppt to 5 ppt; the oyster-growing grounds are separated into upper bay seed beds and lower bay leased grounds (Figure 1); while oyster harvests vary year to year, the oyster population is severely depressed due to MSX and Dermo (another disease of oysters) (Ford et al.) 1996).	**1**
	Total	**9**
Assessment of uncertainties in this assessment (H,M,L) and brief description	Low: The prevalence of the Dermo parasite is well documented in NJ and in other areas of the North Atlantic estuaries.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	M=medium if appropriate management actions are taken (e.g. maintain the salinity regimes in the upper Delaware estuary so that there are low salinities that protect the young oysters from predation and disease organisms (Ford et al.) 1996) and management actions that avoid projects resulting in permanent water withdrawal from the estuary that reduce seasonal variation of fresh water inputs or introduce more salt in the upper Estuary (Ford et al. 1996). Studies needed to document and develop Dermo disease-resistant strains of oysters (Ford & Tripp 1996). Before the resistant strain of *C. gigas* is considered as an alternative to the eastern oyster for culture on the Atlantic coast of the US, studies are needed to assess the ecological impacts of those species in NJ waters. An alternative scenario would be to allow *P. marinus* to spread over the Delaware Bay, including the upper estuary, to foster natural selection and the more rapid development of resistance (Ford, pers. comm.).	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	- (but could improve if management actions taken, as discussed above)	
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L= Low The catastrophic effects have already occurred (Ford, pers. comm.).	

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Link to other Work Groups (e.g., socioeconomic impacts)	Economic impacts of reduced oyster populations in New Jersey.
Extent to which threat is currently regulated or otherwise managed	Specifically, dermo is not regulated. NJDEP's National Shellfish Sanitation Program surveys shellfish growing in waters in the state and classifies them according to the presence and abundance of coliform bacteria and significant sources of potential contamination. Water data are combined with land use, water hydrography and pollution source information to classify the NJ's shellfish growing waters for harvesting. **Studies on Control Measures**: Avoid moving infected seed oysters and avoid planting disease-free seed near source of infection such as native populations on natural beds, pilings, bridges, or pier (Andrews & Ray 1988); remove residual oysters and let grounds lay "fallow" for 1-2 yrs after harvest (Burrell et al. 1984; Gibbons and Chu 1989); Organic and inorganic chemicals that kill the parasite often kill the host as well with the exception cycloheximide that caused a decrease in parasite densities and could be used to curb infections in small lots of oysters (Calvo & Burreson 1994). In the field, elimination of parasitized oysters is the best control (Andrews & Ray 1988).
Barriers to restoration	Management at the local level needs to continue to be coordinated at the state level with respect to managing water withdrawals, controlling river flow through dam construction or channel dredging.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	MSX or Dermo are not caused by water pollution; both are prevalent in clean water as in contaminated water (Ford et al. 1996). A recent study showed that Dermo disease might be worsened by heavy pollution because it can be intensified by exposing oysters to highly toxic sediments (reported in Ford et al. 1996; Chu and Hale 1994)
NJ Primary Sources	
Large business/industry	
Small business industry	
Transportation	
Residential	
Agriculture	
Recreation	
Resource extraction	
Government	
Natural sources/processes	
Orphan contaminated sites	
Diffuse Sources	

Sediment sinks	
Soil sinks	
Non-local air sources incl. deposition	
Biota sinks	

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Issue: Dermo Parasite in Oysters
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Statewide Analysis of Threat

Threat = Dermo (*Perkinsus marinus)* in oysters

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	N/A	N/A	N/A	
Marine Waters	3	3	1	9
Wetlands	N/A	N/A	N/A	
Forests	N/A	N/A	N/A	
Grasslands	N/A	N/A	N/A	
			Total Score	9
			Average Score	1.8

Risk by Watershed Management Region

THREAT = DERMO	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	N/A	N/A	N/A	N/A	N/A
Passaic	N/A	N/A	N/A	N/A	N/A
Raritan	N/A	N/A	N/A	N/A	N/A
Atlantic	N/A	Low	N/A	N/A	N/A
Lower Delaware	N/A	High	N/A	N/A	N/A
Region/Watershed (secondary)					
Urban	N/A	N/A	N/A	N/A	N/A
Suburban	N/A	Low	N/A	N/A	N/A
Rural	N/A	Low	N/A	N/A	N/A

H=high, M=medium, L=low;

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Dioxins/Furans**
Description of stressor	There are several structurally similar dioxins and furans that result from the incomplete combustion of complex organic material in the presence of chlorine or in the manufacture of paper or pesticides and herbicides. There may be small amounts of dioxins and furans formed during natural fire of forested land. This review focuses on two sets of exposures and impacts due to dioxin and furans. One set of impacts are those found in aquatic systems and result from high rates of contamination associated with areas of intensive chemical and industrial production. The second set of exposures related to the deposition of dioxins and furans to terrestrial ecosystems, is much more geographically uniform and arises from a number of sources, most of them associated with combustion. Ecological impacts are difficult to determine for two reasons: Dioxin is a contaminant that most often co-exists with other hazardous chemicals. This is particularly difficult when assessing damages from dioxin in New Jersey aquatic environments. The localized elevated concentrations of dioxin are in heavily industrialized areas with significant contamination from other chemicals. There are no reference conditions available where dioxin is not present. This problem is of particular interest for terrestrial contamination. There are several endpoints that dioxin and furans may cause, but the lack of terrestrial hot spots and pristine areas makes the visible identification of these impacts challenging. Dioxin and furan formation is related to the formation of chlorinated phenols such as pesticides 2,4 D and pentachlorophenol. In most cases of concentrated aquatic contamination, there is a mix of other chlorinated aromatic compounds of varying toxicity. Dioxin is also a combustion by-product. Particular sources of interest include municipal and hospital incinerators, low temperature, back yard incineration and the general combustion of fossil fuels from utility boilers and vehicles. For the rest of this report, we will refer to the complete suite of dioxins and furans as dioxin. The toxicity of the individual congeners is most often indexed to the most potent dioxin, 2,3,7,8 tetrachlorodibenzo-p-dioxin (often referred to as TCDD). It is this compound that is the subject of most study.

	In general, dioxin is an extremely potent toxin, measurable affects are noted at concentrations of parts per trillion. Dioxin is also variable in its impacts depending upon species. Finally, dioxin bioaccumulates due to its fat solubility and slow rate of elimination.
Key impacts selected (critical ecological effects)	For this report, we will focus on two sets of impacts. The general existence of dioxin in terrestrial environments and the existence of "hot spots" in aquatic environments. In aquatic environments, the most sensitive endpoints are the viability of fish eggs and fry. Studies show specific developmental affects under laboratory conditions that are consistent with observations on the viability of these species in areas of elevated contamination. (Cook et al., 1991). At higher concentrations, the viability of other species is affected with a range of biological endpoints. Impacts associated with exposures in terrestrial environments are varied and treated in this report on a case-by-case basis with respect to soil benchmark values.
Exposure Assessment	
Exposure routes and pathways considered	Dioxin associated with terrestrial exposure is originates via air deposition, initially associated with particulates and eventual movement through the food chain. In aquatic environments, dioxin is introduced through direct discharge and from runoff of heavily contaminated soils. Dioxin adheres to the organic fraction of sediment particulates. Sediment dwelling organisms are a primary pathway for dioxin to enter the foodchain, although certain fish species very susceptible to low concentrations in the water column, may be affected and bioaccumulate the contaminant for exposure to other species (Pruell et al., 1993). The concentrations of dioxins are very low in water or in air, but more measurable in soils and sediments. There are three basic measures for determining dioxin exposure; sediment and soil concentrations, concentration in the water column and the most direct measures of exposure are from tissue sampling.
Population(s)/ecosystem(s) exposed statewide	Dioxin is pervasive and present in most species tissues especially notable in this report for terrestrial exposure. Higher concentrations are evident in aquatic species near higher concentration sources. In New Jersey, the Newark Bay complex is a source of elevated dioxin levels due to the past activities of the Diamond Shamrock facility (Bopp et al.,1991). A study of crab tissue shows elevated levels in the Newark/Raritan Bays (NJ DEP, 1985, NYSDEC, 1997).
Quantification of exposure levels statewide	There are national studies showing variations in fish tissue concentrations. Most fish have concentrations less than one part per trillion. Fish from more contaminated urban environments regularly show concentrations approaching 100 parts per trillion with individual animals showing concentrations approaching 1,000 parts per trillion. Specific organs such as the hepatopancreas of the blue crab concentrate the contaminant to levels occasionally exceeding 1,000 parts per trillion (one part per billion.)
Specific population(s) at increased risk	Certain fish species are most sensitive to dioxin effects. Rainbow trout and pike eggs exhibit effects on viability (Helder, 1980 and 1981) and guppies and coho salmon show fin necrosis at water concentrations as low as 0.1 ppt (Eisler, 1986). These effects are also noted when spawning adults have significant contamination (20-100 ppt) and

	pass the contaminants to eggs. (Cook et al., 1991) Aquatic communities in the Passaic River/Newark Bay region are at increased risk due to the high concentrations associated with sediments in the region.
Quantification of exposure levels to population(s) at increased risk	
Dose/Impact-Response **Assessment**	
Quantitative impact-assessment employed	There are few direct impact studies for the terrestrial impacts of dioxins. One area of significantly elevated dioxin concentrations in Seveso, Italy provided evidence of acute toxicological effects, but no evidence of effects from chronic exposure. In contrast, there are significant studies showing that accumulated dioxin in fatty tissues of most species is present at levels that cause biological effect (USEPA, 2000] The acute damages from dioxin in Seveso were deaths in the rabbit and farm animal populations. In the United States, the incident of contamination at Times Beach Missouri resulted in the deaths of horses and birds. There are possible reproductive effects noted in gulls near Lake Ontario, associated with dioxin contamination (Rice and Keefe,) The issue of endocrine disruption is an additional factor to consider. Dioxins and furans are one subset of the chemicals that have been shown to affect hormonal systems in humans and animals (Environment Canada). As with other issues circulating around dioxin, a challenge exists in identifying the relative impact of dioxin as a source of endocrine disruption as compared with other chemical contaminants that also show endocrine effects. Because dioxin has no commercial use, it is only present in tandem with more intentional chemical applications or in combustion along with a wide menu of pollutants. Isolating its effects in ecological systems is therefore, difficult. Compounding this difficulty for endocrine disruption is the uncertainty of endpoints that may result (US EPA). Some of the possible endpoints include yolk synthesis alterations and the population density of molluscs (Gies and Wenzel, 1995) For this report, we can consider that dioxin is one of many endocrine disrupting chemicals and the results of endocrine disruption in New Jersey ecological systems is uncertain but may relate to aquatic species viability, especially amphibians and piscivorous birds. Ecological Benchmarks for TCDD: Terrestrial **Soil**: Oak Ridge National Laboratory calculated a Preliminary Remediation Goal (PRG) of 3.15 x 10^{-6} mg/kg (3.15 parts per trillion) for TCDD in soil for protection of wildlife based on the shrew (Efroymson et al., 1997). A value of 0.00084 mg/kg (840 ppt) was listed for TCDF based on protection of the red-tailed hawk.
	Ecological Benchmarks for TCDD: Aquatic **Surface Water (freshwater)**: Lowest Observable Effect Level (LOEL) for acute toxicity was reported as 10 ppt;

	LOEL for chronic toxicity was reported as 0.01 ppt. (Buchman, 1999). **Sediment**: Freshwater: Upper Effects Threshold (UET): 8.8 ppt (dry wt. Based on 1% total organic carbon, *Hyalella azteca* bioassays). (Buchman, 1999) Marine: Apparent Effects Threshold (AET): 3.6 ppt (dry wt, based on *Neanthes* bioassays). (Buchman, 1999) Tissue Residue (whole body): Based on data in Jarvinen and Ankley (1999): Freshwater: No observed adverse effects levels (NOAELs) ranged from 0.25 to 1.6 ppb. Effect levels ranged from 0.6 to 1,380 ppb. Marine: NOAELs ranged from<0.635 to 1.46 ppb. Effect levels ranged from 0.635 to 6.8 ppb. Therefore, it appears that LOELs are observed in the range of <1 to 5 ppb (<1,000 to 5,000 ppt) whole body residue depending on the species , exposure, and endpoint. Soil Concentrations: No comprehensive study of the concentrations of dioxins/furans in NJ's soils has been conducted. National level studies conducted in the 1980s show urban soils typically contain 51 to 9100 ppt (Travis, Hattermer-Frey and Silbergeld, 1989) in excess of benchmark values. Sediment Concentrations (data from NOAA database): In the Newark Bay region, TCDD concentrations ranged from 0.071 ng/Kg to 13,500 ng/Kg (ppt), with a mean of 307 ppt (365 surface sediment samples). TCDF concentrations ranged from 0.31 to 480 ppt with a mean of 37.3 ppt (365 samples). Total PCDF concentrations ranged from 0.61 to 11,000 ppt with a mean of 533 ppt (131 samples). The mean TCDD sediment concentration of 307 ppt is well above the benchmark (AET) value of 3.6 ppt. For the Passaic River the average TCDD sediment concentration was 493 ppt (range 0.2-13,500 ppt), again, well above the benchmark value. Therefore, impacts to benthic communities would be likely in these areas where the benchmark values are greatly exceeded.

	<u>Tissue Concentrations</u>: Data from the NOAA database involving investigations of the Diamond Shamrock facility and other studies in the Passaic River/Newark Bay region indicate that TCDD concentrations range from 0.87 ppt (blue crab muscle) to 6,238 ppt (blue crab hepatopancreas). Species analyzed included killifish, American eel, softshell clam, striped bass, white perch, carp, and brown bullhead. Striped bass TCDD concentrations (fillets) ranged from 23 to 734 ppt with an mean concentration of 112 ppt (n=10), however this average was skewed by one high concentration (734 ppt). American eel fillet concentrations ranged from 8-160 ppt with a mean of 65 ppt (n=6). Killifish whole body (*Fundulus heteroclitus*) concentrations ranged from 30 to 75 ppt with a mean of 53 ppt. More recent Passaic River data of killifish whole body composites indicated that concentrations ranged from 26.1 to 828 ppt (average of 86 ppt, n=45); white perch (*Morone americana*) whole body concentrations averaged 269 ppt (range 224-352 ppt). **<u>Comparison to Benchmarks</u>**: Using the lower end of the range for tissue residue effects levels, about 250 ppt, indicates that most tissue concentrations are below the benchmark (although some data is based on fillets and not whole body concentrations which are probably higher). However, some of the concentrations exceed the lower benchmarks and approach clearly demonstrated adverse effect levels (e.g., killifish – 828 ppt, striped bass – 734 ppt). In addition, based on the literature it appears that fish early life stages are more sensitive to dioxin than later stages (e.g., adults). Therefore, impacts on fish embryos and larvae could be greater. We should also note that several studies show toxic effects greater than 1,000 ppt, and while only rarely do samples show concentrations at this level, the occasional sample points out the possibility that toxicity is possible from dioxin contamination.	
Risk Characterization		
isk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude) Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery	2-3 Terrestrial ecosystems are exposed to low level dioxins that may result in some biological activity. In the 1980's a study showed that total PCDD/PCDF Concentrations in urban areas, with no known local source of release, average concentrations were greater than 1400 ppt (Travis, Hattemer-Frey and Silbergeld, 1989). At those levels, the dioxin equivalent may be significantly higher than the 3.4 ppt benchmark	Score

3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	Aquatic systems have more complete (but not comprehensive) data from more recent evaluations. The Newark Bay area shows sediment concentrations well in excess of ecological benchmark values. At these levels, the toxicity of dioxin may be most evident. The endocrine effects that may occur in certain species can not be linked solely to dioxins because of the prevalence of so many estrogen and anti-estrogenic compounds, and the diffuse nature of the effects (Environment Canada, USEPA).	2-3
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	2.5 Impacts range from “rare” (2) in most systems, to “often and continuing” (4) in the Passaic River/Newark Bay area.	2.5
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	2 –Terrestrial impacts may be widespread, but the number of species that are directly affected is likely to be low. In aquatic systems, the highly contaminated portions of Raritan/Newark bays represent a significant portion of the statewide estuarine area. Other aquatic systems of the state also have some levels of dioxin contamination, but impacts are expected to be low.	2
	Total	12-15
Assessment of uncertainties in this assessment (H,M,L) and brief description	M – There is a lack of information regarding the levels of dioxin in most species and there is a lack of information regarding the impacts on most species. Routine monitoring for dioxins/furans in soils, sediments and tissue is not conducted in the state. The existence and level of a threshold concentration at which dioxins/furans causes impacts is still under debate.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	M – It is possible that additional information will suggest more or less risk. However, the prospects of increased risks from dioxin absent other contaminants will be very difficult studies to conduct.	

Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, ! , =, ≡; where + is improvement), and brief description.	+ Studies of sediments show that the deposition of dioxins and furans in the environment peaked during the 1960s when the manufacture and use of dioxin-contaminated pesticides was at its height. Since that time dioxin deposition rates have decreased between 50 and 90 percent. EPA estimates reductions on the order of 80% between 1987 and 1995 with additional reductions likely due to regulation of municipal and medical waste incinerators. However, dioxin is a persistent contaminant and the return to background levels of exposure may require several decades (US EPA, 2000).
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L – Potential for future releases resulting in catastrophic impacts are low. The accidental release in Seveso, Italy caused some short-term mortality of rabbits and farm animals, but it is not clear that any longer term ecological effects resulted. The current use of land near the chemical plant is as a park.
Link to other Work Groups (e.g., socioeconomic impacts)	Contamination of aquatic organisms (e.g., fish and crabs) with dioxin has resulted in crabbing bans in the Newark Bay Complex; fish advisories for all fish in the Passaic River; and fish advisories for striped bass, American eel, bluefish (over 6 lbs.), white perch, and white catfish in the Newark Bay Complex.
Extent to which threat is currently regulated or otherwise managed	Dioxin releases are regulated from incinerators and paper producing mills. The management of contaminated industrial sites reduces the possibility of significant additions to aquatic hot spots.
Barriers to restoration	Removal of dioxin from soils and sediments is impractical based on the general distribution of the pollutant and the low concentrations. The relatively high costs associated with dioxin/furan analysis of soil, sediment and biological tissues acts as a barrier for data collection.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	Most current sources of dioxin are from incinerators, especially those that operate at lower temperatures. Back yard burn barrels are important sources in areas where residents use such devices. (Note: “backyard” burning of trash, leaves, etc is prohibited in NJ)
Large business/industry	L
Small business industry	L
Transportation	L
Residential	L
Agriculture	L
Recreation	L
Resource extraction	L
Government	L
Natural sources/processes	L

Orphan contaminated sites	Higher but very case-specific depending upon the potential for mobilizing the contaminants
Diffuse Sources	
Sediment sinks	M – decreasing
Soil sinks	M – decreasing
Non-local air sources incl. deposition	L-M
Biota sinks	L

Summary Statement: The observable impacts from dioxin alone are small to moderate. However, dioxin is a potent toxin and its presence in the environment may provide an additional stressor to already challenged species. In addition, the locally high concentrations of dioxin in contaminated sediments contribute to the overall toxicity of those sediments. Dioxin is a good example of the application of risk as a metric for considering regulation. Exceedances of benchmark values in both terrestrial and aquatic environments suggest that dioxin is altering biological systems. Decreasing that “risk” is a practical response in the absence of conclusive data on the impacts from dioxin, alone. Comparing dioxin to other chemical factors places it within the range of possible impacts. This conclusion is different than the impacts that may result from physical changes to the environment where impacts are more obvious, more dramatic, and less speculative.

In summary, the Severity and Irreversibility for the aquatic ecosystems are based on a mixed observation of localized severity in the Passaic River that is higher in concentration than other locations in the state, a gradual reduction in the contamination at the hot spots. For marine systems, the severity is less, but the geographic extent is larger and the reversibility may be slower because of the continual migration (some human accelerated, and some natural) of river sediments to the marine system.

Issue: Dioxins/Furans
Author: GMI
Version: 05/02/01

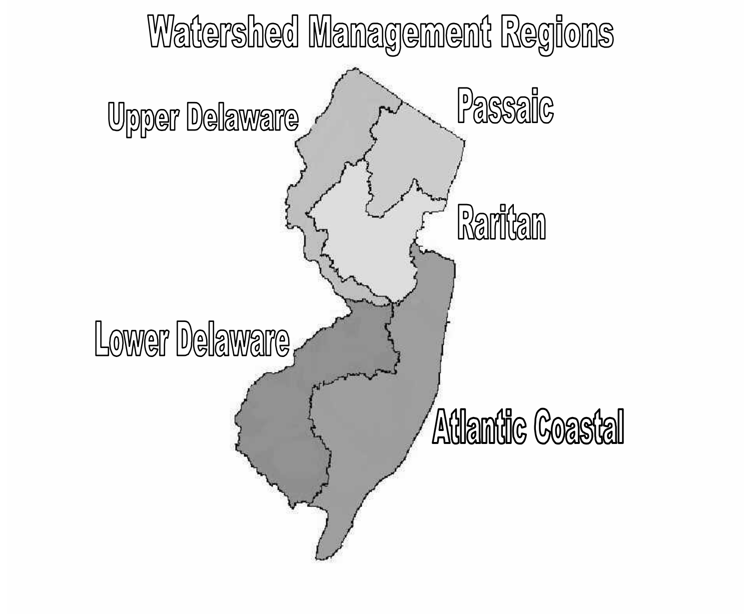
Statewide Analysis of Threat **Threat = Dioxins and Furans**

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	3	2	18
Marine Waters	3	3	2	18
Wetlands	2	3	2	12
Forests	2	3	1	6
Grasslands	2	3	1	6
			Total Score	60
			Average Score **(Total ÷ 5)**	**12**

Risk by Watershed Management Region

THREAT =	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L	NA	L	L/M	L/M
Passaic	M	H	L	L/M	L/M
Raritan	M	M/H	L	L/M	L/M
Atlantic	L	L/M	L	L/M	L/M
Lower Delaware	L	L	L	L/M	L/M
Region/Watershed (secondary)					
Urban	M-H	M-H	L	L-M	L-M
Suburban	L	L	L	L-M	L-M
Rural	L	L	L	L-M	L-M

H=high, M=medium, L=low, NA = not applicable



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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Dredging**
Description of stressor	Dredging is "the removal of sediment from the bottom of a water body … for the purpose of increasing water depth, or the widening or deepening of navigable channels to a newly authorized depth or width." (NJDEP, 1997) Dredging has been used for over a century to facilitate human use of waterways. There are two different classifications of dredging: new dredging, which involves an area that has not previously been dredged (including the deepening of an already existing channel), and maintenance dredging, which is done in order to maintain water depth, or channel width and depth, at original dredging levels. The New Jersey Office of Dredging was established on June 1, 1998 to handle the approval of applications for dredging projects.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	**Habitat/ecosystem health:** Dredging affects the viability and population size of many aquatic species, such as submerged aquatic vegetation (SAV) and the many species that depend on SAV for habitat and ecosystem stability. The greatest effects of dredging are on immobile species, such as those attached to the sediment being dredged, even if only during certain stages of their life (e.g.) juvenile lobsters). New dredging eliminates habitat, while maintenance dredging keeps habitat in a continually disturbed state. The actual dredging process contributes to air and water pollution through the use of fossil fuel-powered equipment. The disposal of dredged material can have many adverse effects because it is usually contaminated at higher levels than the disposal areas. The most common contaminants are dioxins, polychlorinated biphenyls (PCBs), heavy metals (i.e. zinc, cadmium, lead, nickel, chromium, copper and mercury), pesticides, and polycyclic aromatic hydrocarbons (PAHs). Leakage from disposal areas, especially Confined Disposal Facilities (CDFs), can cause surface and groundwater contamination. In addition, bioaccumulation of these contaminants often occurs in organisms that inhabit the CDFs or are exposed to sediment that has been resuspended in the dredging process. There is also habitat loss caused by the creation of CDFs for the placement of dredged material. Rock blasting to create new or deeper channels is another habitat disturbance (Baier, 14 April 2000).

	Ecosystem function Dredging causes the resuspension of much sediment in the water, which can block sunlight from reaching aquatic organisms, and thereby compromise their ability to grow and provide food for other species. This resuspended sediment can also cover and smother organisms attached to the bottom. If the timing of dredging activities is not properly controlled, there can be significant impacts to fish populations, including endangered species, especially if their spawning habitat is disturbed or removed by dredging. Dredging also impacts aquatic ecosystems by increasing salinity levels through sediment displacement. (N.J.A.C. 7:7E-3.2).
Key impacts selected (critical ecological effects)	Spread of contamination Resuspended sediment Habitat loss
Exposure Assessment	
Exposure routes and pathways considered	There are three major regions into which dredging in New Jersey is classified: the New York Harbor (Region I), the Atlantic Coastal Basin (Region II), and the Delaware Bay and River (Region III). The NY Harbor area consists of northeastern New Jersey (north of Sandy Hook), and includes the Port of New York and New Jersey. It is heavily industrialized and has been dredged in order to allow ship travel into the Port of New York and New Jersey. The Atlantic Coastal Basin stretches from Sandy Hook to Cape May, and is mostly a recreational boating area. The third region consists of the Delaware Bay, the tidal Delaware River and their associated tributaries from Cape May to Trenton. It is the most diverse region, encompassing both recreational and industrial uses.
Population(s)/ecosystem(s) exposed statewide	Almost all aquatic organisms found in these three regions.
Quantification of exposure levels statewide	Note: These numbers are for the 23-month period from June 1, 1998 until May 1, 2000. (Source: Office of Dredging and Sediment Technology) NY Harbor: (Most of these projects are state or federally funded.) 43 total projects were approved, corresponding to a total volume of 74,677,502 cubic yards of dredged material. Of these, 6 of the projects are new dredging (not maintenance), and account for 57,560,400 cubic yards of dredged material. Previously, Region 1 had averaged about 4,000,000 cubic yards of dredged material per year. Almost all of the dredged material is disposed of in the Historic Area Remediation Site (HARS) in the ocean, or in underwater or upland Confined Disposal Facilities (CDF). Atlantic Coastal Basin: 89 total projects resulting in 883,804 cubic yards of dredged material were approved; most were private projects. Of this amount, 66% was disposed of in CDFs, 27% onsite, 3% in “beneficial uses”, such as landfill cover, and 4% was disposed of in other ways.

	Delaware Bay and River: 29 total projects, amounting to a total volume of 5,604,160 cubic yards of dredged material. 99% of this goes into CDFs, while the other 1% goes to beneficial uses.	
Specific population(s) at increased risk	Bottom-dwelling species, or species at stages in their lives when they live at or are attached to the bottom: e.g.) submerged aquatic vegetation, larval bay scallops, juvenile lobsters, oyster beds, blueback herring (Greene, 3 May 2000)	
Quantification of exposure levels to population(s) at increased risk	Cannot or has not been accurately determined. (Greene, 3 May 2000)	
Dose/Impact-Response Assessment		
Quantitative impact-assessment employed	Data on the volume of dredging that occurs, contamination levels, and area of the ocean floor that is converted into disposal sites for the dredged material.	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	In all three regions, dredging results in habitat reductions and alterations, causing populations to decline. However the populations do tend to recolonize the area after a few years, and dredging has never been found to be the cause of a major population decline (Greene, 3 May 2000, and Pabst, 3 May 2000).	3
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing	NY Harbor: The amount of dredging per year has more than quadrupled since the beginning of the channel deepening project in 1999 (NJDEP, 1997, NJDEP 1999,	5

3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Office of Dredging). Atlantic Coastal Basin and Delaware regions: Amount of dredging is increasing only slightly, so it is relatively constant year to year. This is because the majority is maintenance dredging, which must be done yearly.	 4
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	New York Harbor Atlantic Coastal Basin and Delaware regions:	3 2
	Total NY Harbor: Atlantic and Delaware:	 45 24
Assessment of uncertainties in this assessment (H,M,L) and brief description	Medium: Much of the data used to make these conclusions comes only from the period 1998-2000 (since the Office of Dredging opened). Since this is a short period of time, these data might not be fully representative of the past or future.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	Medium: More study into the scope of the effects of resuspended sediment caused by dredging could show that even more habitat is affected than has been predicted. Also much study must be done on the effects of the different disposal methods for dredged material.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	(0): Neutral change is expected in the near term based on the planned level of dredging and current methods. There are increasing possibilities for beneficial disposal methods for the dredged material that virtually eliminate contamination and bioaccumulation problems. Decontamination treatments are also being developed. Implementation of these methods would be rated (++).	
Potential for catastrophic impacts (H,M,L) and brief description	Low: Dredging has been occurring for over a century and it is unlikely that the dredging process will drastically change.	
Link to other Work Groups (e.g., socioeconomic impacts)	Economic costs of various sediment disposal methods and costs of reduced fisheries due to habitat loss. Reduction in employment and income due to bioaccumulation of contaminants in marketable seafood. Human health impacts due to consumption of this contaminated seafood.	
Extent to which threat is currently regulated or otherwise managed	High. There are extensive dredging regulations and application and testing procedures. Several departments deal specifically with dredging in New Jersey, such as the NJDEP Office of Dredging, and offices at the U.S. Army Corps of Engineers. New dredging regulations are instituted by lawmakers and the EPA.	
Barriers to restoration	Maintenance dredging is necessary in order to preserve shipping channels, which are vital to the economy. This prevents full restoration of the dredged area. The desire to dredge for personal, recreational uses among New Jersey	

	residents is also very high (Baier, 14 April 2000).
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	M: contribute to the high contamination levels found in the sediments in Region I and part of Region III.
Small business industry	L
Transportation	L (unless shipping is included under transportation)
Residential	L
Agriculture	M/L: runoff of pesticides contributes to sediment contamination
Recreation	H: recreation is the impetus for much of the dredging that occurs in Regions II and III.
Resource extraction	L
Government	M: government is responsible for the majority of the dredging in Region I
Natural sources/processes	L
Orphan contaminated sites	NA
Diffuse Sources	
Sediment sinks	NA
Soil sinks	NA
Non-local air sources incl. deposition	NA
Biota sinks	NA

Issue: Dredging
Author: Rebecca Jones
Version: 05/19/00

Statewide Analysis of Threat Threat = Dredging

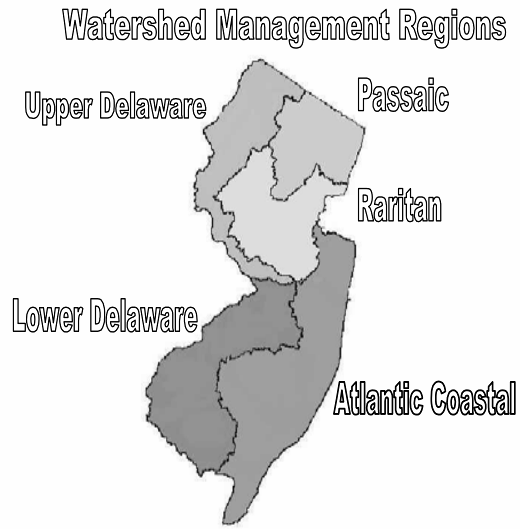
Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	4	2	24
Marine Waters	3	4.5	2.5	34
Wetlands	4	2	2	16
Forests	NA	NA	NA	0
Grasslands	NA	NA	NA	0
			Total Score	74
			Average Score	14.8

Risk by Watershed Management Region

THREAT= Dredging	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L	NA	L	NA	NA
Passaic	L	H	L	NA	NA
Raritan	L	M	L	NA	NA
Atlantic	L	M	L	NA	NA
Lower Delaware	L	M	L	NA	NA
Region/Watershed (secondary)					
Urban	L	H	L	NA	NA
Suburban	L	M	L	NA	NA
Rural	L	M	L	NA	NA

H=high, M=medium, L=low, NA = not applicable

Issue: Dredging
Author: Rebecca Jones
Version: 05/19/00



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Issue: EHD Virus in Deer
Author: Mary Downes-Gastrich
Version: 05/02/00

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**EHD Virus in Deer** (Epizootic Hemorrhagic Disease)(NJ serotype) in NJ white-tailed deer (*Odocoileus virginianus)*
Description of stressor	Lethal virus spread by gnats
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	EHD is an acute, infectious, often fatal *viral* disease of some wild ruminant animals. EHD has a high mortality rate and was responsible for killing more than 60 deer in 1999 in southwestern NJ (Salem and Cumberland counties); however, DEP is testing blood and tissue samples to determine whether EHD has returned to NJ to attack animals. EHD seems to appear in 20 yr. cycles and NJ is about due for an outbreak (Paul Tarlowe, DF&W, pers. comm.). Historic outbreaks and effects: Disease can occur annually but in NJ the following outbreaks have been documented (20 yr. cycles): October 1999: EHD caused rapid hemorrhaging and shock in approximately 60 white-tailed deer found dead in October 1999 in Salem and Cumberland counties; 8 of the animals were found floating in a Salem Co. waterway; desperate animals fled into water to cool their high fevers. 1975: EHD killed about 1,000 deer in Hunterdon, Warren, Morris and Sussex counties. 1955: EHD killed more than 700 deer in Somerset, Morris and Essex counties. EHD outbreaks have occurred in S. Dakota, N. Dakota, Wyoming, Alberta, CA. Suspected outbreaks in other mid-western states. Most information in this template was found in the website: (http://www.healthnet.org/programs/promed-hma/9909/msg00062.html. by A.B. Clark of the Rose Lake Wildlife Disease Laboratory (Michigan Department of Natural Resources Homepage).
Key impacts selected (critical ecological effects)	Recent deaths in 60 white-tailed deer (20 yr. cycles) in 2 southwestern NJ counties. Any beneficial aspects of EHDV-1 in controlling deer populations is not known.
Exposure Assessment	
Exposure routes and pathways considered	Mode of transmission: Culicoides biting fly or gnat (*Culicoides variipennis*). EHD is characterized by sudden onset, developing signs of disease within 7 days of infection, hemorrhage and between 8-36 hrs following onset, deer pass into a shock-like state and die.
Population(s)/ecosystem(s) exposed statewide	EHD can have a significant effect upon the white-tailed deer population in a given area, reducing numbers drastically. While EHD can be transmitted to other wild ruminants, it rarely causes disease. Recently, EHD has killed only white -tailed deer in 2 NJ counties (Salem/Cumberland); historically, kills in other counties. There is no evidence that EHD crosses over to humans.

Quantification of exposure levels statewide	Occurrence of disease is currently in 2 counties (Salem/Cumberland). Information provided above. Methods were developed for virus isolation.	
Specific population(s) at increased risk	White-tailed deer (*Odocoileus virginianus)*	
Quantification of exposure levels to population(s) at increased risk	Not known. However, high mortality if deer exposed. EHD can have a significant effect upon the deer population in a given area, reducing numbers drastically.	
Dose/Impact-Response Assessment		
Quantitative impact-assessment employed	No data	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score 4
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	EHD is a single epizootic which does not recur (excepting 20 yr. Cycles) in NJ. While EHD is not treatable or preventable (Greg Huljack, NJDEP), the disease does <u>not</u> wipe out entire deer herds and is not a statewide threat. There is no danger to humans, livestock or pets at this time (Boston Globe, 1999).	2

Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Low frequency based on occurrences – while it can occur annually in some areas; usually high mortalities have been occurring in 20 yr. epizootic cycles.	2
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	In 1999, EHD killed 60 white -tailed deer in given locations in 2 counties (Salem/Cumberland) in WMAs # 17, 18. In previous years, kills were in specific locations in WMAs #s 1, 2, 11, 6 in Hunterdon, Warren, Morris, Sussex, Somerset, and Essex Counties	1
	State: Average Score Total	1
Assessment of uncertainties in this assessment (H,M,L) and brief description	L=Low; EHD has been well documented in NJ; the clinical signs are known and frequency of disease has been measured; there are no known treatments or cures for the disease.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	L- Low because of few current studies on the EHD and documentation of occurrences. While the risk of EHD to U.S. livestock is low, EHD is morphologically and biochemically similar to the bluetongue (BLU) virus serotype of orbiviruses (Mecham, 1999). While EHD viruses are highly pathogenic to white-tailed deer, it is not known whether EHD may cause bluetongue-like illness in cattle (Mecham 1999). ELISA (enzyme linked immunosorbent assay) procedures have been developed that detect serum antibody to EHD viruses (Mecham 1999). The hypothesis is that if BLU and EHD viruses are co-circulating, relatively rare reassortment events might explain the emergence of more virulent EHD virus strains capable of causing clinical disease in cattle (Mecham 1999). Reassortment experiments in both the vector and the host might be helpful (Mecham 1999).	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	(0) The potential for future changes in the underlying risk from this stressor is not known at this time.	
Potential for catastrophic impacts (H,M,L) and brief description	L= Low. While EHD can cause high mortalities in given populations, it does not affect the entire deer population.	
Link to other Work Groups (e.g., socioeconomic impacts)	Not likely	
Extent to which threat is currently regulated or otherwise managed	DF&W monitors the occurrence of EHD in NJ and documents the cases in counties where it occurs.	

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Barriers to restoration	No known effective treatment or control for EHD
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	
Small business industry	
Transportation	
Residential	
Agriculture	
Recreation	
Resource extraction	
Government	
Natural sources/processes	EHD transmitted by insect vectors (gnats)
Orphan contaminated sites	
Diffuse Sources	
Sediment sinks	
Soil sinks	
Non-local air sources incl. deposition	
Biota sinks	

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Boston Globe. Sept. 8, 1999. Epizootic hemorrhagic disease, deer – USA (New Jersey) http://www.healthnet.org/programs/promed-hma/9909/msg00062.html. by A.B. Clark of the Rose Lake Wildlife Disease Laboratory (Michigan Department of Natural Resources Homepage).
Mecham, J.O. 1999. Epizootic Hemorrhagic Disease Virus of Deer; does it pose a risk to U.S. Livestock? Website: http://www.usaha.org/speeches/ehd97.html
Statewide Analysis of Threat

Issue: EHD Virus in Deer
Author: Mary Downes-Gastrich
Version: 05/02/00

Threat = EHD (Epizootic Hemorrhagic Disease) in white-tailed deer (*Odocoileus virginianus)*

Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	N/A	N/A	N/A	NA
Marine Waters	N/A	N/A	N/A	NA
Wetlands	2	1	1	2
Forests	2	1	1	2
Grasslands	2	1	1	2
			Total Score	6
			Average Score	1.2

Risk by Watershed Management Region

THREAT = EHD	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	N/A	N/A	Low	Low	Low
Passaic	N/A	N/A	Low	Low	Low
Raritan	N/A	N/A	Low	Low	Low
Atlantic	N/A	N/A	Low	Low	Low
Lower Delaware	N/A	N/A	Low	Low	Low
Region/Watershed (secondary)					
Urban	N/A	N/A	Low	Low	Low
Suburban	N/A	N/A	Low	Low	Low
Rural	N/A	N/A	Low	Low	Low

H=high, M=medium, L=low;

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	**Findings**
Hazard Identification	
Stressor	**Endocrine disruptors**
Description of stressor	Endocrine disruptors are synthetic organic chemicals that mimic, inhibit the action of natural hormones (80+ vertebrate hormones), or alter the normal regulatory function of the immune, nervous, and endocrine systems (EPA, 1997). The National Research Council used the term Hormonally Active Agent (HAA) to describe substances that possess hormone-like activity, regardless of mechanism (NRC, 1999). ED/HAA result from intrinsic properties of chemicals intentionally used in products and/or unintentionally released into the environment that involve single or multiple exposures to chemicals, mainly synthetic, or to naturally occurring endocrine active substances. The universe of chemicals used in significant commercial quantities that have either not been or inadequately tested for endocrine disruptor activity exceeds 70,000. While some of these chemicals are classified as toxic and are listed on the EPA's Toxic Release Inventory, most have not been assessed for endocrine disruptor activity. The universe of chemicals that have been adequately tested for comprehensive ED activity is likely less than 1,000 chemicals. Among the chemical compound classes that contain suspected EDs are chlorinated pesticides (DDT, DDE, Dioxin etc), polychlorinated biphenyls (PCBs), plasticizers (e.g., phthalates), organometallic compounds (tributyltin), and pharmaceuticals (birth control pills, and other endocrine active pharmaceuticals used in osteoporosis, menopause, and other treatments). In this document the terms ED, endocrine mimics, endocrine modulation, gender benders, and HAA are used synonymously for the sake of simplicity.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	Wildlife – adverse reproductive and developmental outcomes, both structural and functional (altered phenotypic sex ratio, lactation parameters [shortened lactation may compromise the ability of offspring to grow and develop optimally thereby affecting the ability to survive], that can be manifested during any time period, from development through maturity. These chemical stressors may affect all the specific impacts listed depending on the specific circumstances involved. The following are examples of impacts that can occur from exposure to endocrine disrupting chemicals in the environment. Tributyltin interrupts the biological integrity of invertebrates such as snails by interfering with normal hormone metabolism. Tributyltin (TBT) used, as an anti-fouling agent on boat hulls has been associated with ecological impairments in various invertebrates in near shore marine environments up and down our coasts.

TBT at very low concentrations, which result from TBT leaching from the boat finishes, causes a condition known as imposex in certain invertebrates. Imposex results when a genetic female snail develops both female and male genital systems, with the male organs superimposed over female organs. Another effect known as intersex, seen in periwinkle species occurs where the female organs are modified toward the male form. Fully developed cases of intersex and imposex result in female sterilization. Consequently these types of ED conditions lead to altered sex ratios, reduce the number of young, and lead to the elimination of entire populations in contaminated areas. One study of snails ranging from Rhode Island to Georgia found that imposex scores were significantly higher in every pair of marinas studied (Smith, B. S., 1981). While regulations are phasing out the use of TBT on smaller boats, the problems it causes are expected to continue as its use is still permitted on larger vessels. It should be noted that TBT is also being covered under metals.

In New Jersey, chlorinated pesticides, such as DDT, DDE, etc., and chlorinated biphenyls have been associated with the historical reduction of predator avian species in the Delaware River Basin. The DEP Endangered Species Program has been studying this problem for years. Their research has shown that addled eggs, non-viable unhatched eggs, contain high levels of these chlorinated compounds. Eggs that have successfully hatched while still containing detectable pesticide residues are lower in pesticide concentrations (Clark, *et al*., 1998). Whether or not other species such as otter and mink have been impacted in New Jersey from eating pesticide-contaminated species, primarily fish, has not been assessed. Effects from these chemicals can adversely impact biological integrity, biodiversity, and ecosystem health and ecosystem function. It should be noted that PCBs are also being treated separately.

The DEP Bureau of Water Monitoring has a statewide stream-monitoring program that monitors stream and water quality by sampling and assessing the condition and diversity of benthic invertebrates. They have identified a number of sites where populations of invertebrates known as Chironomids have a higher percentage than normal of malformed mouth and antenna parts.

In five of seven rivers in Northern Europe, not particularly known for contamination or industrial dumping, and in several places in the U.S., contaminants dissolved in the water are associated with the feminizing of male fish (gender-bending). That is, genetic males, possessing male chromosomes, are found to contain female reproductive tracts. ED contaminants contained in these waters are capable of inducing high levels of a female protein involved in egg-laying, called vitellogenin, in male fish (Kaiser, 1996 and Arukwe *et al*., 1997). In Washington state, up to 84% of phenotypic females in the wild salmon tested positive for male genetic markers while none of hatchery-raised female fish tested positive. This feminizing phenomenon has also been reported in several other U.S. locations. Contaminants associated with these phenomena are reported to be nonylphenol, and estrogenic compounds (perhaps excreted components of birth control pills and other medications) contained in sewage outfall waters. Microinjection of estrogenic o'-DDT into Medaka in laboratory studies basically supports the plausibility of this hypothesis (Edmunds, *et al*., 2000). Feminization of male fish could adversely impact biological integrity, biodiversity, ecosystem health and function.
health and function.

	Human epidemiology studies have shown that women with high body burdens of polychlorinated compounds, such as PCBs and DDE, have 40 to 60 percent shorter lactation periods (Rogan, *et al*., 1986; Rogan *et al*., 1991; and Galden and Rogan 1995). While, to the best of our knowledge, it has not been examined in mammalian wildlife species, but if it were present, it might be associated with population declines that have been observed in some species. Should this effect occur in mammalian wildlife species, it could adversely impact biological integrity, biodiversity, ecosystem
Key impacts selected (critical ecological effects)	Chemicals possessing ED activity frequently have low water solubility and as a consequence are very persistent in the environment. These chemicals may be found in air, soil, sediments, rivers, lakes, oceans, and in the food chain of many species. Virtually all the key ecological effects may be impacted depending on the chemical compound in question.
Exposure Assessment	
Exposure routes and pathways considered	Aquatic, food – oral ingestion (which may include incidental soil or sediment ingestion), Respiration – secondary absorption from gill respiration and dermal absorption).
Population(s)/ecosystem(s) exposed statewide	Terrestrial wildlife, aquatic, and avian species
Quantification of exposure levels statewide	Difficult to make generalized accurate statement considering paucity of tissue specific species data. Certainly qualitatively excessive exposure levels exist in some areas that act as contaminant sinks (e.g., rivers and bays such as Newark Bay Complex and Delaware River, but there are probably other areas whose concentrations exceed what is considered compatible with a healthy ecosystem.
Specific population(s) at increased risk	Fish, crabs, crustacean, benthic invertebrates, avian, and mammalian wildlife species.
Quantification of exposure levels to population(s) at increased risk	Very little tissue data exists for biota exposed to EDs. Where available, it is frequently excessive, since, concentration data is usually not sought unless there is a suspected problem.
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	
Risk Characterization	
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude) Assessment of severity/irreversibility	Many species are currently known or suspected of being threatened/endangered, some from known clauses, others from as yet unknown causes. While still controversial, there are an increasing number of investigators who suspect EDs.

5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery		Score
3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		3
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	The concentrations of chlorinated pesticides possessing ED activity whose use has been severely limited or eliminated by legislation is generally stabilizing or decreasing very slowly. Others, (e.g., pharmaceuticals) whose use has not been restricted, are probably increasing.	4
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State impacted 4- 25-50% of the State impacted 3- 10-25% of the State impacted 2- 5-10% of the State impacted 1- <5% of the State impacted	Difficult to estimate accurately. Estimate 20 - 40 % of wildlife population may be affected, hence the 3.5 rating.	3.5
	Total	42
Assessment of uncertainties in this assessment (H,M,L) and brief description	M. In aquatic environments many species are either known or suspected of being impacted. Prey species of birds are known to have either impacted/or threaten reproduction. Mammalian, non-piscivorous, non-prey, species (e.g., herbivores) are possibly the least impacted at this time. The level of uncertainty is due to the large number of	

	untested compounds.
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	H. Additional chemical concentration data are required to better characterize both the severity and extent of ED. Systematic periodic monitoring data is necessary to properly assess whether the ED contamination/exposure is improving or degrading. This information is also necessary for the prudent allocation of resources.
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	=. It is anticipated that the risks of some of stressors is currently poorly understood and may be underestimated. Additional data using more refined measures and more sensitive endpoints may in the short term indicate the problem is worse than is currently realized. That being said, additional data, analysis, and evaluation are the necessary first step to correcting these problems. Additionally, prior to approximately 1995 when more chemical specific techniques became more commonplace, chemical analyses using gas chromatography with electron capture detection usually only reported the analyte being sought for whatever eluted during a given retention time window. As a consequence, for example, if PCB was being analyzed and a chlorinated pesticide eluted during the same retention time window, only PCB would be reported out, even though other chemicals may have been present. The point is that in earlier data sometimes only PCB or chlorinated compounds were reported in the data even though other agents were present.
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L: Low potential for widespread catastrophic impacts, however some populations are likely to collapse prior to clean ups and/or before remediation measures are accomplished.
Link to other Work Groups (e.g., socioeconomic impacts)	Linked to human health, human endocrine disruptor, socioeconomic (tourism – bird watching), and sport fishing and hunting.
Extent to which threat is currently regulated or otherwise managed	While there are many regulations presently affecting the production, use, and discard of chemicals, the levels at which they are presently regulated may not be effective in protecting the resources against biomagnification/concentration as one ascends the food chain. In addition, a significant extent of the present widespread contamination existed prior to regulations taking effect. That is, the regulation was reactive, occurring after the fact.
Barriers to restoration	Industry is reluctant to accept additional wastewater or other type of emission controls since they usually adversely impact production costs and profits. Consumers desire, purchase, and use products that have harmful environmental impacts when discarded in the environment. Additional tax money to pay for restoration of damaged ecosystems is not popular with either industry or the public at large.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	H in past, moderating now (M).
Small business industry	M
Transportation	L

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Residential	M
Agriculture	H
Recreation	L
Resource extraction	L
Government	L
Natural sources/processes	L
Orphan contaminated sites	L
Diffuse Sources	
Sediment sinks	H, very high
Soil sinks	L
Non-local air sources incl. deposition	M, can be an unrecognized major contributor for some chemicals
Biota sinks	M

Summary Statement:

Endocrine Disruption results from a subset of chemicals that possess inherent hormonal activities either as a result of their chemical structure and/or their ability to mimic other hormonal compounds or interfere with receptor sites of cells that are intimately associated with cellular regulatory/control functions. ED is real and is likely to grow worse unless the factors that have contributed to the emergence of this problem are not eliminated or at least substantially reduced. All exposure pathways and populations/ecosystems are at risk from ED to some degree. The effects of ED can vary from subtle to severe and from temporary to permanent at any life stage of an organism and can have profound and lasting consequences that may not be apparent until much later in the organisms life cycle. The score given is a result of both what is already known and the uncertainties that are associated with the present knowledge base.

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Statewide Analysis of Threat   Threat = Environmental Endocrine Disruptors

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	3	5	2.5	37.5
Marine Waters	3	~4 – 5	3	40.5
Wetlands	3	4	1	12
Forests	1	3	2	6
Grasslands	1	3 – 4	2	7
			Total Score	103
			Average Score (Total ÷ 5)	20.6

Risk by Watershed Management Region

THREAT = Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L-M	NA	L	L	L
Passaic	H	H	L	L	L
Raritan	H	H	H	L	L
Atlantic	M	M	M	L	L
Lower Delaware	H	H	H	L	L
Region/Watershed (secondary)					
Urban	H	H	L	L	L
Suburban	H	M	L	L	L
Rural	L	L	L	L	L

H=high, M=medium, L=low, NA = not applicable

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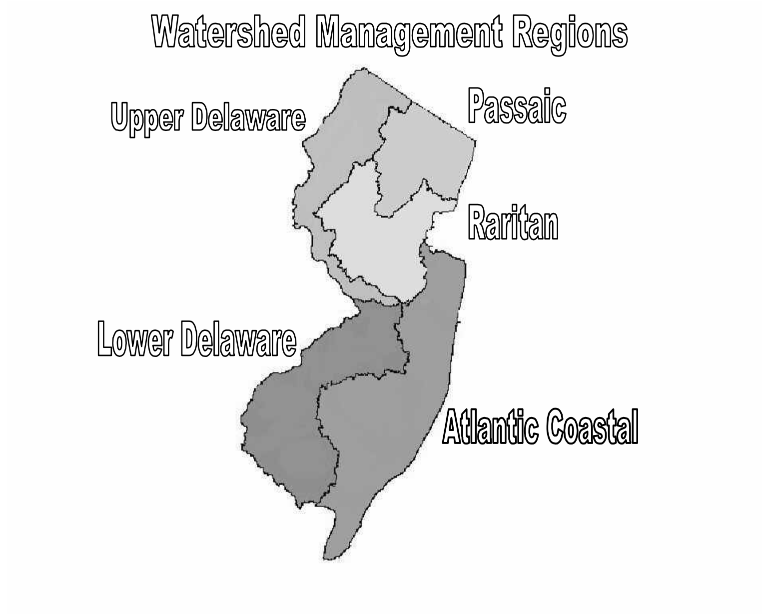

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	**Estremely Low Frequency and Electromagnetic Fields (ELF/EMF)**
Stressor	Time-varying electric and magnetic fields from 3 hertz (Hz) to 3,000 Hz, jointly designated ELF by the National Institute for Occupational Safety and Health (NIOSH), the National Institute of Environmental Health Sciences (NIOSH) and the U.S. Department of Energy (DOE).[1]
Description of stressor	Electric fields arise from electric charges. They govern the motion of other charges situated in them. When charges accumulate on an object, they create a tendency for like or opposite charges to be repelled or attracted, respectively. The strength of that tendency is characterized by the voltage and is measured in units of volts/meter (V/m) or kilovolts/meter (kV/m). Electric fields are strongest close to the device emitting them and diminish with distance. Common materials such as wood and metal, shield against them. Almost none of the electric field penetrates into an animal or human body.[2] However, the presence of a person or an animal perturbs an electric field.[3] Magnetic fields arise from the motion of electric charges (current). They govern the motion of moving charges. Their strength is measured in units of amperes per meter (A/m) but is usually expressed in terms of the corresponding magnetic induction measured in units of tesla (T). In some cases, another unit called the gauss (G) is commonly used for measuring magnetic induction. (1 microtesla = 10 milligauss (mG)). Magnetic fields are strongest close to the device emitting them and diminish with distance. They are not shielded by most common materials and can easily pass through them. They easily penetrate an animal or the human body without any significant attenuation.[2] Because animals or humans do not perturb magnetic fields, the field inside the animal is the same as the external field regardless of body shape or size. However, in terms of magnetically induced electric fields, body shape and size is a consideration. For example, in order to achieve induced electric fields in rodents comparable to those induced in humans by a given magnetic field, stronger external fields are needed for the rodent.[3] Electric and magnetic fields are often categorized by their frequency, which is measured in hertz (Hz). The frequency describes how many wave peaks pass by in one second of time. The most common ELF frequencies in the environment are 25 and 60 Hz. 60 Hz is the frequency that electrical power operates at in the US and trains primarily operate at a fundamental frequency of 25; some operate at 60 Hz. There is a submarine communications system (Project Seafarer) which emanates from Michigan and Wisconsin that operates around 76 Hz. This will not be addressed because it is uncertain what the field levels are in New Jersey from this system. The primary action in biological systems by ELF-EMF fields is the induction of electrical charges and currents.[2]

Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	The majority of field effects on animals and plants focused on the electric field and studies were conducted prior to 1988, before the focus shifted to the effects of magnetic fields on humans. Very little research has been done at ELF-EMF frequencies other than 60 Hz. <u>Laboratory animals</u> – Most of the research that has been performed on animals after 1988 has been done with the intention of extrapolating data to humans. (To date, there has not been good correlation between human epidemiological findings and experimental animal data.) Animal carcinogenic studies of ELF-EMF have been performed at levels of exposure generally much higher than what humans or animals in a typical environmental setting would encounter. Another problem with these studies is that the field frequencies and intensities are more uniform that "real world" conditions.[4] The laboratory data in animal models are inadequate to conclude that exposure to ELF-EMF alters the rate or pattern of cancer. Also, there appears to be no evidence to indicate that ELF-EMF affects animal hematological or clinical chemistry parameters or, alters reproductive performance or developmental toxicity.[4] The effects of ELF-EMF on animal immune systems have demonstrated no consistent effects. Similarly, studies of the effect of ELF-EMF fields on melatonin are conflicting[4] and will probably continue to receive more attention in the future. (Melatonin is a hormone secreted by the pineal gland. Light controls the secretion of melatonin. It helps regulate daily biological rhythms such as the sleep-wake cycle. It also appears to influence mood and behavior.) Wildlife and many domestic species such as sheep breed only at certain times of the year. Melatonin provides the animals' reproductive system with the necessary time-of-year information. If melatonin patterns are indeed altered, the timing of reproduction may be affected.[5] Research over the years has revealed that some creatures can perceive electric and magnetic fields but there is no clear-cut evidence that these fields are harmful at environmental intensities.[3] <u>Bees and Birds</u> In the special case of bees and avian species, the observed sensitivity to ELF time-varying fields may originate through a field interaction mechanism similar to that which is believed to underlie the response of these animals to low-intensity, static magnetic fields. Deposits of magnetite crystals have been identified in bees and avians, and the magnetic force interaction with these ferromagnetic inclusions may produce autonomic responses. From a theoretical perspective, it is unlikely that a time-varying ELF field could orient or produce significant motion of the magnetite inclusion. Rather, the time-varying force produced by the field may trigger somatosensory responses.[6] <u>Insects</u> - One of the species whose behavior seems to be affected by electric fields are honeybees. Results of studies indicate that bees in hives located beneath high voltage power lines in fields of 7 kV/m to 12 kV/m occasionally show decreased honey and brood production and may fail to survive the winter.[7] Whether the effects are due to the direct action of the electric fields or indirectly due to minute discharges to the bees is not yet resolved. Shielding the bees from the electric field by using a wire mesh screen, restores their normal behavior.[8] Bees also appear to become irritable at fields of 7 kV/m[7] and some lower productivity has been reported at levels as low as 2 kV/m[3] but not lower than 1.8 kVm.[6] field strength is of this magnitude. The overall health of such trees appear to remain unaffected.[8]

Birds - Avian collisions and interactions with utility structures such as power lines, towers and guy wires present a persistent and widespread problem. Birds have been electrocuted and behavioral perturbations have been observed.[7] Studies of songbirds near transmission lines also indicate that vegetation on the right-of-way, rather than electric or magnetic fields, is the primary factor influencing usage and behavior. For birds, however, some additional considerations arise.[3]

Where transmission lines cross open country, some birds such as hawks and eagles often use the towers for perching and nesting. Although there are some shielding effects from tower parts, birds nesting on these structures can be exposed to electric fields for long periods. Birds nesting on Bonneville Power Administration (BPA) lines have been studied to determine whether there are harmful effects from the energized lines. A sample of hawks nesting on 500 kV and 230 kV line towers produced about the same average number of young as were reported for hawks nesting in trees and cliffs.[3]

Large birds such as eagles can be electrocuted if they contact a conductor and grounded hardware, or if they contact two conductors of different phases. These problems are generally associated with distribution lines of 12 kV to 69 kV. Transmission line conductors are usually spaced far enough apart so that bird electrocutions seldom occur. Special line designs have been developed for protecting raptors and other birds from power line electrocutions. These are described in a report distributed by the Raptor Research Foundation. It is not known if any of these special designs exist in New Jersey. Most waterfowl and other birds during low altitude flight typically react to the presence of the lines by altering flight direction or altitude to avoid colliding with the lines.[3]

Some studies have produced evidence indicating that birds can perceive alternating current magnetic fields comparable in magnitude to those of the earth's direct current fields (500 mg). Whether such fields disrupt avian flight orientation, provide environmental location information to flying birds, or have no effect at all is not clear.[3]

Fish – Some fish are known to be sensitive to very weak, low frequency electric and magnetic fields. Sharks and some other species have special organs (ampullae of Lorenzini) for detecting biofields from other fish and probably the earth's fields. For example, skates were shown to respond to 5 Hz square wave fields of only 0.001 mV/m, and stingrays oriented to uniform electric fields as small as 500 nanovolts/m. American eels and Atlantic salmon reportedly can also perceive low frequency electric fields of 7 to 70 mV/m. However, 45 to 75 Hz electric fields up to 20 V/m have been reported to have little effect, if any, on the behavior of bluegill fry. A 10 kV/m transmission line electric field in air would produce a field in water of around 1 mV/m.[3] Wild mammals – Any effects of electric and magnetic fields on wildlife are subtle and difficult to identify. When mammals (or birds for that matter) are within or beneath vegetation, the vegetation largely shields them from the electric field from the power lines. When mammals such as deer or elk move through areas of low-growing vegetation, they may be subject to induced body currents, shocks, and perception effects. Because the larger animals are normally grounded to a degree though their feet, it is unlikely that they experience shocks in these fields. It is possible that some wildlife species are able to detect weak induced currents. Based on studies with laboratory animals, wildlife may be able to detect electric fields through such means as hair stimulation (or feather stimulation in the case of birds).[3]

One study of deer and elk movement in Idaho under a 500 kV line reported no observable effects due to the electric and magnetic fields. Some animals were attracted to the cleared right-of-way for feeding. However, during hunting season, game animals tended to avoid the right-of-way and other similar clearings during daylight. Another researcher examined the effects on small mammals on a right-of-way in Tennessee containing two 500 kV lines. In hardwood forests, small mammals were more abundant on the cleared right-of-way than in the adjacent forest. In pine forests, the reverse occurred. In both areas, the right-of-way was used by some species not present in the adjacent forest. Use of the various areas by small mammals appeared to be strongly influenced by vegetation composition and distribution, which affects cover and food availability. BPA has studied small mammals for several years under a prototype 1,200 kV line and has found no adverse electric field effects on the mammals. They observed that animals were most abundant on the right-of-way and in the nearby control areas during the first 2 years of construction and operation. Mammal abundance on the right-of-way and control areas were observed to decline in the subsequent years. After initial right-of-way clearing, tall brush had become re-established on the right-of-way, thus shielding small mammals from the electric field.[3]

Livestock – Results of research thus far have generally shown that transmission line electric fields do not affect livestock behavior or health. A comprehensive study of livestock living near a 765 kV line in Indiana was sponsored by American Electric Power Service Corporation. Included in the study were beef and dairy cattle, sheep, hogs and horses on 11 farms. These lines produced electric fields up to 12 kV/m. The study found no evidence that health, behavior, or performance of livestock were affected by electric fields.[3]

Many other studies have been done on cattle fertility, calf mortality and milk production. In general, most studies show no adverse health effects in fields ranging from 4 kV/m to 12 kV/m although occasionally some studies have reported decreased cattle fertility and higher incidences of calf mortality and birth defects. A BPA study reported that cattle under a 1,200 kV/m prototype line spent more time under the line when it was de-energized.[3] Conversely, the author (D. Wenke) recalls receiving information from federal government scientists of cow s appearing to prefer standing beneath transmission lines 500 kV and higher. The proposed theory for this behavior was that the fields were acting as a stressor to the cows' system, thus triggering the release of endorphins, which made the cows "feel good." At the time of writing this risk analysis, the author was neither able to confirm nor deny these claims.

An explanation for conflicting evidence for effects on livestock may possibly be explained by the presence of "stray voltages". Although not a transmission line electric field effect, stray voltages on equipment in barns have been found to adversely affect the health and production of dairy cows and other livestock. The sources of the voltages, which result in annoying shocks, include ground faults, improper wiring, and unbalanced loads on electrical distribution systems. Methods are available for identifying the sources and for mitigating problems caused by stray voltages.[3]

In Iowa, a study was done of crossbred swine raised beneath a 345 kV line. The line produced a maximum field of 4.2 kV/m. The behavior and performance of 30 swine under the line over a 91-day period was compared to those of 30 control animals located away from the line. No effects of the line were found on body weight, carcass quality, behavior, or feed intake.

	A second phase of the study involved swine reproduction. Findings indicated no effect of the 345 kV line on pregnancy rate, frequency of birth defects, or on weight gain of young.[3] A long-term multigenerational teratology study on Hanford miniature pigs exposed continuously to 60 Hz, 30 kV/m electric fields was completed at the Pacific Northwest Laboratories. The pigs were also assessed for changes in growth, hematology, and serum chemistry profiles, humoral and cell-mediated immunity, blood hormone levels, peripheral nerve function, behavior, reproductive function, and prenatal developments. Nothing remarkable was observed except there were some developmental anomalies noted. However, it is not certain if the abnormalities were the result of the electric field.[6] <u>Plants</u> – Observations on the effects of electric fields upon plant growth and germination have indicated that the fields associated with transmission lines are not strong enough to have any detrimental effects. Plants with rounded leaves have been found to be unaffected by electric fields up to 50 kV/m. Above that value, small corona discharges in the air appear on the leaf edges. This is a result of the field enhancement around the leaf tips. As a consequence, there is limited drying of the leaf tips but no further damage to the overall health of the plant. On plants with pointed leaves, corona starts at a lower field level (about 20 kV/m).[7] Trees alongside or under the line could reach up to where the
Key impacts selected (critical ecological effects)	Biological integrity and ecosystem health.
Exposure Assessment	
Exposure routes and pathways considered	Exposure to ELF-EMF is though immersion in the fields. Major sources of ELF electric and magnetic fields which have the potential to affect the environment are transmission and distribution lines and train lines.
Population(s)/ecosystem(s) exposed statewide	All plants and animals near power lines and train lines. All birds can gain access to any line.
Quantification of exposure levels statewide	Magnetic field levels on the ground near high voltage transmission lines typically range between 1 and 110 mg[8] and may be as high as 150 mg.[7] Electric field levels on the ground near high voltage transmission lines typically go up to 5 kV/m[8] and may be as high as 7 kV/m.[7]
Specific population(s) at increased risk	All honeybees, wildlife (mammals, fish) and livestock under power lines and all birds.
Quantification of exposure levels to population(s) at increased risk	Honeybees, fish, mammals and livestock may be exposed to magnetic fields from 1 to 110 mg and possibly levels as high as 150mg. Birds will receive the highest exposure, but an estimation of the intensities of these fields is unknown. Honeybees, mammals and livestock may be exposed to electric fields from 0.1 to 5 kV/m and possibly levels as high as 7 kV/m. As in the case of the magnetic field, birds will receive the highest exposure, but an estimation of the intensities of these fields is unknown. Fish will receive lower exposures because the water will serve to reduce the electric field. (A 10 kV/m electric field in air produces a field in water of around 1mV/m.)[3]
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	Research papers were reviewed to determine what field levels elicited effects in different animals. Considered New Jersey sources (primarily power lines) which could emanate benchmark field levels.

	Honeybees – show effects at 2kV/m. These field are primarily produced by 500 kV line or 230 kV double circuit lines of which there are many in New Jersey. Fish – It is estimated that a field as high as 10 kV/m would not be typically found in New Jersey and this seemed to be the limit for detection by field-sensitive fish. Wild mammals – information is conflicting and seems to center around lines 345 kV and higher. The same lines at risk to the honeybees could also impact here. Livestock – the same analysis that applies to wild mammals is used here. However, since livestock cannot always regulate their exposure by avoiding lines, this puts them at a slightly greater risk than wild animals. Birds – have access to all lines and will be subject to highest fields encountered by living creatures.	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery	Livestock – 2 Honeybees – 2 Birds – 2 Wild Mammals – 1.5 Fish – 1	2 2 2 1.5 1

3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 – Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Livestock – 2 Honeybees – 2 Birds – 2 Wild Mammals – 1 Fish – 0.5	2 2 2 1 0.5
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	Livestock – 2 Honeybees – 2 Birds – 2 Wild Mammals – 1 Fish – 1	2 2 2 1 1
	Total Livestock Honeybees Birds Wild Mammals Fish	 8 8 8 1.5 0.5
Assessment of uncertainties in this assessment (H,M,L) and brief description	H – The effects of ELF-EMF seem to be conflicting in the case of wild mammals and livestock, bees and birds. M- Need more information on the magnetic field effects on fish. L – for plants	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data	L – The effects of this stressor seem so complicated, it is unlikely that more experimentation will yield consistent results with clearer risk estimates.	

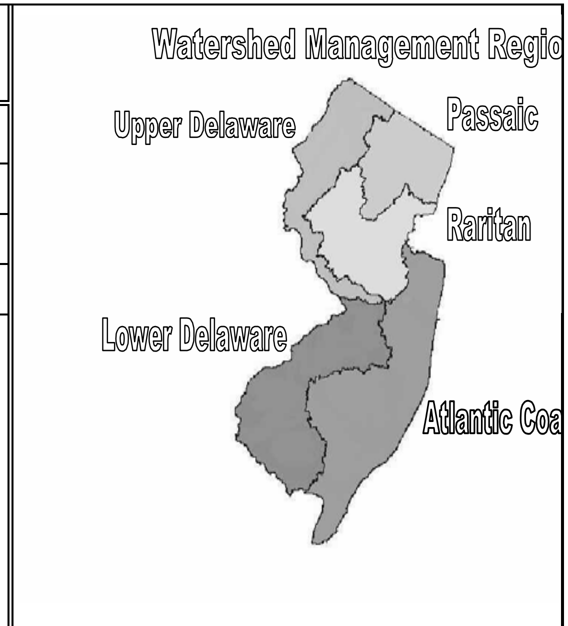
needs)	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, ! , =, ≡; where + is improvement), and brief description.	+, Some utilities are voluntarily reducing fields from power lines that are new or being modified.
Potential for catastrophic impacts (H,M,L) and brief description	None (L)
Link to other Work Groups (e.g., socioeconomic impacts)	?
Extent to which threat is currently regulated or otherwise managed	State guideline exists to restrict electric field at the edge of transmission line rights-of-way to 3 kV/m.
Barriers to restoration	N/A
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	H – producers and users of electricity
Small business/industry	L – users of electricity
Transportation	H – overhead electrical train lines
Residential	M – users of electricity (primary and secondary distribution lines to residential areas)
Agriculture	L – users of electricity
Recreation	L – users of electricity
Resource extraction	L – users of electricity
Government	L- users of electricity
Natural sources/processes	N/A
Orphan contaminated sites	N/A
Diffuse Sources	
Sediment sinks	N/A
Soil sinks	N/A
Non-local air sources incl. deposition	N/A
Biota sinks	N/A

Issue: ELF-EMF
Author: Tucillo/Gillespie/Wenke
Version: 07/31/00

Summary Statement:
Time-varying electric and magnetic fields from 3 hertz (Hz) to 3,000 Hz have been designated as ELF-EMF (extremely low frequency electric and magnetic fields). Electric fields arise from electric charges and magnetic fields arise from the motion of electric charges. Any time electricity is used, electric and magnetic fields are generated. Therefore, ELF-EMFs are virtually ubiquitous. Magnetic fields are of more concern than electric fields. The major sources of magnetic field exposure in the environment are electric power transmission lines and primary distribution lines. Therefore, exposed populations will be found within transmission lines rights-of-way and under distribution lines. All plants and animals are affected to some degree, although animals seem to be affected more than plants. The animals that appear to be most sensitive to magnetic fields are honeybees and birds. Livestock are more at risk than wild animals as they are often relegated to living near the lines and don't have the ability to migrate away from them. Although risks from this stressor are small, there is some evidence to indicate that behavior, reproduction and population vigor may be affected to some slight degree. Risk and threat scores should be low for this stressor since research results on adverse bioeffects from these fields are contradictory. Yet the pervading nature of this stressor in the environment warrants continued investigation since ELF-EMF exposure cannot be recognized as entirely safe.

Statewide Analysis of Threat Threat = ELF-EMF

Ecosystem	**Severity Irreversibi lity**	**Frequency**	**Magnitude**	**Score**
Inland Waters	1	1	1	1
Marine Waters	1	1	1	1
Wetlands	2	2	1	4
Forests	2	2	1	4
Grasslands	2	2	1	4



Total Score	14
Average Score (Total ÷ 5)	2.8

Risk by Watershed Management Region

THREAT =	ECOSYSTEM

Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	L	NA	L	L	L
Passaic	L	L	L	L	L
Raritan	L	L	L	L	L
Atlantic	L	L	L	L	L
Lower Delaware	L	L	L	L	L
Region/Watershed (secondary)					
Urban	L	L	L	L	L
Suburban	L	L	L	L	L
Rural	L	L	L	L	L

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Issue: Floatables
Author: Thomas/Buchanan
Version: 06/01

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Stressor:
Floatables
– the presence of discarded trash such as plastic bottles, plastic bags, plastic foam packing material, and other floating debris in surface waters, primarily estuarine and marine waters (see Photo).

Floatables enter surface waters from many sources including storm drains, combined sewer outfalls (CSOs), littering, and pleasure and commercial vessels. CSOs have been identified as a primary source of floatables including tampon applicators, condoms and plastic floatables. During rainfall, increased flows overload the capacity of sewerage treatment plants and the flows are bypassed directly to surface waters.

Floatables have been responsible for numerous beach and bay closings in New Jersey, although the numbers have decreased significantly during the 1990s. The impacts of floatables include the potential for human health impacts, as well as socio-economic impacts. However, floatables can also impact aquatic life. Ingestion or entanglement of floatables (e.g., plastic bags) can lead to strangulation, internal blockages, or other harm to birds, turtles, fish, marine mammals, or other wildlife. This impact on ecosystems as a whole is judged to be small in New Jersey, especially because the incidence of floatables has decreased and this trend is expected to continue. However, since monitoring of impacts on aquatic life is not conducted in NJ the actual impacts are not fully understood.

Several actions have been taken by New Jersey to reduce the magnitude and impacts of floatables. NJDEP has an EPA approved CSO Control Strategy (NJDEP, 1996), and under the New Jersey Sewage Infrastructure Improvement Act, all municipalities operating CSOs are to provide abatement measures required by the State. All municipalities must develop a Long-term Control Plan with a goal of implementation by 2004 (NJDEP, 1998). In addition, the NJDEP operates the Clean Shores program that uses inmate labor to remove floatables from tidal shorelines. Crews have removed over 85 million pounds of floatables from the shoreline of the state.

Risk/Severity Rating: L – this stressor is primarily a problem in marine and estuarine waters. A rating of low was given due to the management actions taken and the decreased incidence.

Confidence Rating (Uncertainty): M – data is available on the magnitude of floatables in the state, and impacts on aquatic life are known, however, little data or monitoring of the impacts in NJ's waters are available.

Catastrophic Potential: L – this stressor has little potential to cause widespread drastic negative impacts.

Trend (Potential for future changes in the underlying risk from this stressor): (+) CSO improvements and continued control/removal programs should result in decreased impacts in the near future.

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Issue: Floatables
Author: Thomas/Buchanan
Version: 06/01

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Photograph showing floatables (e.g., plastic bottles) along a shoreline on a New Jersey tidal river. (Photo by G. Buchanan)

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Geese** (Branta canadensis)
Description of stressor	Populations of resident Canada Geese have increased over the past two decades, particularly in urban, suburban and agricultural habitats, causing adverse socioeconomic and ecological effects. Socioeconomic effects include impacts to water quality, particularly in reservoir systems, damage to lawns in parks, golf courses and other maintained areas from herbivory and droppings, health risks associated with droppings, agricultural damages, and air/vehicular traffic impacts. Ecological effects include adverse impacts to aquatic systems, via changes in nutrient budgets affecting eutrophication, effects of herbivory on abundance and diversity of aquatic plants, spread of diseases transmitted by waterfowl, and the potential for increased interspecific competition affecting the abundance of other waterfowl species. The overpopulation of resident geese has been caused largely by landscape level changes in land use creating favorable habitat in suburban areas where predation and hunting pressures are less, and by agricultural practices allowing waste grain to remain in fields as a food source for wintering populations of geese.

Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	<u>Biological Integrity</u> – Overpopulation of resident geese may affect the biological integrity of ecosystems within the State of New Jersey, as well as elsewhere along the Atlantic Flyway. The biological integrity of aquatic systems used by resident geese is a primary ecological concern; management of resident geese via harvesting represents a challenge since nonresident populations have been declining in recent years (NJDFW 1992). Canada geese were extirpated in the Eastern United States during European settlement, and reintroduced into urban/suburban habitats in the 1940's (Cooper and Keefe, 1997). Within two decades geese were breeding in Eastern cities, and quickly grew at exponential rates (Cooper and Keefe, 1997). Biologists have since defined "resident" geese as birds that breed south of 47 degrees latitude (Shaeffer and Malecki 1990); resident populations are now found in all 15 states of the Atlantic flyway, as far south as Florida (Hindman and Ferrigno 1990). Populations of resident geese in New York, Pennsylvania and New Jersey account for 45% of the eastern population; the population of breeding resident geese in New Jersey was estimated at 50,000 in 1989 (by DFW, 1998), 3,600 individuals in 1989 (Hestbeck 2000), 80,000 in 1997, and 100,000 in 1998 (NJDFW 1998; 2000). Populations in New Jersey increased dramatically in the 1980's and have continued to increase since then (NJDFW 1992). Nonresident Canada geese in New Jersey are primarily from the Atlantic Population, which are geese that nest in Labrador, Newfoundland, and much of Quebec, and winter primarily in the DelMarva peninsula and southern New Jersey (NJDFW 1992). This population has declined precipitously in recent years (NJDFW 1992); the extent to which this drop may be attributable to competition with the resident population, and/or hunting regulations focused on thinning the resident population is unknown.

The biological integrity of ecosystems is potentially affected by overabundance of geese in a number of ways. A primary concern is affects of nutrient inputs into aquatic communities from feces that may affect the composition of plant communities present in suburban lakes and waterways. Through eutrophication, the integrity of these water bodies may be compromised (see Habitat/Ecosystem Health below).

Biodiversity

Without effective management, there is considerable risk that future geese populations in New Jersey will be dominated by resident individuals that are genetically and behaviorally adapted to human environments. Resident geese have a larger body size that enables them to winter further north than the Atlantic population (Lefebvre and Raveling 1967), and their survival may be higher because of increased familiarity with local foraging sites, and avoidance of hunting areas (Johnson and Castelli 1994). The effects of this population shift toward individuals that are non-migratory or only migrate short distances to find open water, on other populations of geese (e.g. the Atlantic population) are not well understood. Higher populations of geese may also compete with other species of native waterfowl for foraging resources and nesting sites, potentially affecting overall species diversity as well as the abundance of rarer species of waterfowl and other water birds.

Geese also influence their environment via herbivory, which favors certain less palatable plant species over others, (Conover 1991), and may even result in barren areas temporarily devoid of vegetation. Although this usually occurs on lawn areas, it results in changes in the herbaceous plant communities present that may affect other species as well. Significant damage to wild rice marshes has been reported in the Maurice River area, and damage to cranberry bogs in the Pinelands area is increasing (NJDFW, 2000).

Habitat/Ecosystem Health Effects of overabundant geese on habitat and ecosystem health in New Jersey are largely focused on aquatic ecosystems. Canada geese droppings are a major contribution to phosphorus loadings in suburban lakes, particularly during fall months (Moore et al, 1998). The same authors noted that the problem is likely to get worse with global warming. Absolute inputs of total phosphorus from geese into urban and suburban lakes of the Northeast area are likely to increase with warmer conditions associated with climate change, because ice cover in winter is unlikely to form on lakes in this region and geese will overwinter there. Manny et al (1994) reported the phosphorus loadings from waterfowl such as Canada geese accounted for 70% of the phosphorus entering Wintergreen Lake in southwestern Michigan from external sources, and concluded that the input of nutrients lowered the water quality of the lake by creating hypertrophic conditions. Increased phosphorus loadings can lead to higher primary productivity (e.g. algae and macrophytes), which in turn creates a higher oxygen demand on the lake. As a result, habitat for fish and other aquatic species may be adversely impacted, impacting the entire aquatic food chain.

Fecal droppings from Canada geese may also result in increased levels of coliform bacteria in aquatic systems (Klett et al 1996). As a result, diseases may spread amongst waterfowl populations or other populations of other species, including humans, that may ingest the contaminated water.

Ecosystem Function

Aquatic ecosystems may function differently with higher populations of geese.

	As herbivory increases and more nutrients present in plant material are converted into fecal matter, aquatic systems become enriched, which further spurs productivity. As a result, nutrient cycling may occur more rapidly. **In addition, increased interspecific competition with other waterfowl species, increased rates of disease, and effects on the diversity and abundance of vegetation species in aquatic environments may result from increased population densities of herbivores such as geese.**
Key impacts selected (critical ecological effects)	**Nutrient inputs to aquatic systems; Potential impacts to non-resident geese**
Exposure Assessment	
Exposure routes and pathways considered	The resident Canada goose population has evolved from favorable habitat conditions, and climatic change resulting in open water areas during winter in the MidAtlantic states that have made long distance migration unnecessary. Locally, overabundant Canada goose populations have resulted from: ▪ Land use changes favoring increased urban and suburban habitats with preferred food items, such as open lawn areas with fertilized Kentucky blue grass (*Poa pratensis*) and other turfgrass species near water bodies (Conover 1991, Conover and Kania 1991); ▪ Reduction or elimination of predators; ▪ Reduction or elimination of hunting pressure or other means of population control (NJDFW 1992); ▪ Agricultural practices allowing large amounts of waste grain to remain in fields over winter (Conover and Kania 1991); ▪ Feeding geese in urban and suburban habitats.
Population(s)/ecosystem(s) exposed statewide	Water bodies (lakes, ponds, streams and rivers) statewide. Urban and suburban habitats with open lawns, and agricultural fields statewide.
Quantification of exposure levels statewide	The statewide resident goose population was estimated at 80,000 in 1997, about 15% of which was harvested during the September season, and 100,000 in 1998. A special winter harvest has recently been initiated, with the objective of further controlling resident populations. The two winter season areas were chosen because they primarily contain resident Canada geese with relatively low proportions of Atlantic population geese. The hunt areas chosen are the only areas of New Jersey where the number of wintering Atlantic population geese is relatively small and meets USFWS criteria for winter Canada goose seasons. Unfortunately, the state's central and lower Delaware Valley counties, while containing abundant resident geese, also contain large numbers of migratory geese during winter and do not meet USFWS criteria for winter seasons. Thus, resident geese may pose the greatest problems within these areas.
Specific population(s) at increased risk	Primary populations/ecosystems at risk are urban and suburban lakes (via water quality degradation), urban and suburban parks, golfcourses, etc. (recreational ecosystems) (primarily socioeconomic effects). Canada Goose Atlantic Population is at risk, but it is unclear whether it is related to resident geese, or management programs (e.g. hunting seasons) geared toward resident geese, or other factors.
Quantification of exposure levels to population(s) at increased risk	Quantification to some affected water bodies (e.g. Kensico Reservoir in New York) has been provided in the literature; however no statewide surveys of goose impacts on water quality or aquatic ecosystems have been conducted.

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Dose/Impact-Response Assessment		
Quantitative impact-assessment employed	Qualitative assessment based on 1) data from the Northeastern United States suggesting sharp increases in the population of resident geese, 2) the geographic extent of lakes, ponds and other bodies within urban, suburban and agricultural habitats statewide, and 3) complaints of homeowners and public health officials regarding resident geese.	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		**Score**
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	Effects would be reversible by both short-term and long-term management programs designed to 1) reduce resident goose populations, 2) discourage goose use of urban and suburban lakes via habitat modification (e.g. planting unpalatable species, shrubs along the shoreline, etc.). Without additional management, serious impacts to the structure and function of lakes and other water bodies could result via nutrient inputs and coliform contamination.	**2 – 3**

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Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decad 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	As resident geese populations grow, water quality problems in urban and suburban water bodies are likely to increase.	3-4
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	Most water bodies in urban and suburban areas of the state are now utilized by geese, although detailed population data by water body are not available, and would change temporally. While the Atlantic population of the Canada goose has declined and is only now beginning to recover, resident goose numbers have increased dramatically statewide from about 50,000 in 1990 to 80,000 in 1997, and approximately 100,000 in 1998. A special September harvest was instituted in 1995, and more recently a winter harvest was instituted. These seasons may not reduce the overall resident goose population, but are designed to curb the growth rate of that population.	3
		(18-36) 27
Assessment of uncertainties in this assessment (H,M,L) and brief description	M – limited NJ-specific data is available on geese impacts on ecosystems.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	L – additional research of the impacts of geese on ecosystems is needed, including nutrient input to waterways, interspecific competition, and impacts to biodiversity.	

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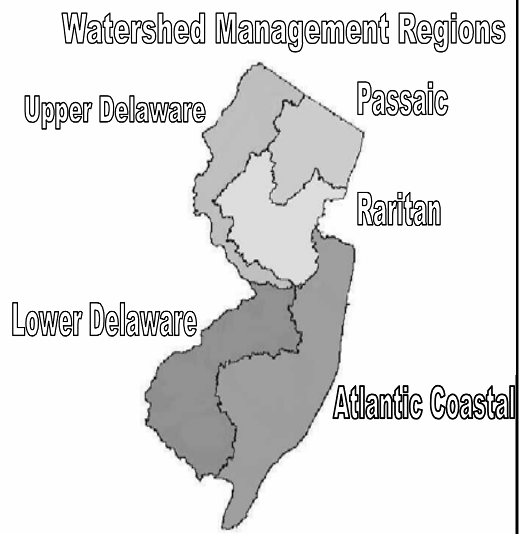
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, ! , =, ≡; where + is improvement), and brief description.	= under future no action conditions + if future population control procedures are effective
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L
Link to other Work Groups (e.g., socioeconomic impacts)	Socioeconomic impacts include adverse impacts on water quality, potential health risks and negative aesthetics associated with fecal matter in parks, on golf courses, etc.
Extent to which threat is currently regulated or otherwise managed	Presently the NJ Division of Fish and Wildlife sets harvest quotas in conjunction with the North Atlantic Flyway Council. Individual permits may be obtained from U.S. Fish and Wildlife Service to control local populations of resident geese. However, resident geese continue to impact their environment. Short-term deterrent methods include harassment with noise making devices, by dogs or other means. Longer term methods include habitat modification around shorelines of ponds and lakes.
Barriers to restoration	Local ordinances or conditions (e.g. private property ownership, park regulations or location next to residential areas, etc.) prohibiting hunting or other means of effective population control or habitat management.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	L
Small business industry	L
Transportation	L
Residential	M
Agriculture	H
Recreation	H
Resource extraction	L
Government	H (parks, regulations)
Natural sources/processes	H
Orphan contaminated sites	L
Diffuse Sources	
Sediment sinks	L

Soil sinks	L
Non-local air sources incl. deposition	L
Biota sinks	L

Summary Statement:

Statewide Analysis of Threat Threat = Overabundance of Canada Geese

Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	3-4	3-4	4	50
Marine Waters	1	0.1	1	0.1
Wetlands	3-4	3-4	3	38
Forests	Na	Na	Na	Na
Grasslands	3	3-4	3	32
			Total Score	120.1
			Average Score (Total ÷ 5)	24



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Risk by Watershed Management Region

THREAT =	*ECOSYSTEM*				
Watershed Management Region	Inland Waters	Wetlands	Grasslands	Forests	Marine Waters
Upper Delaware	H	M-H	M	NA	L
Passaic	H	M-H	M	NA	L
Raritan	H	M-H	M	NA	L
Atlantic	H	M-H	M	NA	L
Lower Delaware	H	M-H	M	NA	L
Region/Watershed (secondary)					
Urban	H	M-H	M	NA	L
Suburban	H	M-H	M	NA	L
Rural	M	M	M	NA	L

H=high, M=medium, L=low, NA = not applicable

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Issue: GMO
Author: Buchanan
Version: 05/15/02

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Stressor:
Genetically Modified Organisms (GMOs)

Issue Summary: Genetically modified organisms (GMOs) involve the alteration and/or movement of genetic material (genes) within or transfer to an organism (i.e., genetic engineering). This can include the transfer of a gene from one unrelated species (e.g., bacteria) to another species (e.g., corn). GMO crops that are currently used nationally include corn, cotton, and soybean. The potential benefits of one type of GMO (i.e., plant-incorporated pesticides) are reduced pesticide use (i.e., from spraying) and increased crop yield. Potential ecological impacts include adverse effects on non-target organisms, development of pest immunity, and genetic exchange between transformed organisms and unaltered organisms. Both the USEPA and USDA regulate GMOs. Testing to date indicates low risk to the species tested with the exception of butterflies. These species are similar to target organisms for plant-incorporated pesticides (e.g., *Bt* corn). EPA concluded that the available information indicated a very low probability of risk to monarch butterflies in areas beyond the near edge of cornfields (EPA, 2001). However, there is a low probability of monarch larvae exposure to a toxic level of *Bt* corn pollen inside and near the edge of cornfields. Overall, the risk from GMOs was deemed to be low. If research identifies adverse ecological impacts from GMOs, data on the extent of GMO use in NJ crops and other organisms should be collected. Potentially impacted areas/ecosystems could then be identified for study.

Severity: Low

Uncertainty: High. No data was available on impacts or extent of use of GMOs in NJ.

Trend: ?? Use of GMOs is increasing nationwide. Expected additional field monitoring and data will help determine the impacts of various GMOs. It is not known whether this additional data will result in a change in the estimated risk.

Potential for Catastrophic Impacts: Low

Introduction

Genetically modified organisms (GMOs) involve the alteration and/or movement of genetic material (genes) within or transfer to an organism (i.e., genetic engineering). This can include the transfer of a gene from one unrelated species (e.g., bacteria) to another species (e.g., corn). The altered species is also called a transgenic organism. According to the U.S. Department of Agriculture (USDA, 2000a), the acreage with genetically engineered crops has grown from 8 million acres in 1996 to more than 67 million acres in 1998. Worldwide, herbicide tolerant crops (e.g., tolerant to glyphosate) account for approximately 75% of all acres planted with GMO crops, with soybeans making up approximately two-thirds of these acres (Benbrook, 2002). Approximately 15% of the acres are planted with GMOs, predominantly cotton and corn, that have incorporated a natural insecticide from the bacterium *Bacillus thuringiensis (Bt)*(Benbrook, 2002). Other GMO crops have both herbicide tolerance and *Bt* endotoxins.

There are both far-reaching benefits and potential impacts with the use of GMOs. Benefits include the reduced usage of pesticides (e.g., reduced crop spraying), increased crop yield, associated economic benefits, and development of foods with desirable traits (e.g., herbicide tolerance, shelf-life, disease resistance, etc.). A number of potential ecological impacts have been posed; these include adverse effects on non-target organisms, development of pest immunity, and genetic exchange between transformed organisms and unaltered organisms. Development of pest immunity to a natural pesticide such as *Bacillus thuringiensis (Bt)* endotoxin would have serious impacts on future use of *Bt* pesticides.

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One public concern is the effects of plant-incorporated pesticides on non-target organisms, specifically the Monarch butterfly based on laboratory studies of exposure to *Bt* corn pollen. Another concern is the release or exchange of the genetic modification to related wild species.

Genetically altered foods/crops and examples of the genes transferred include (ICTA, 2002):
Canola – (glufosinate tolerant): phosphinothricin acetyltransferase gene from *Steptomyces viridochromogenes*
Corn – (insect protection): *cryIA* (c) gene from *Bacillus thuringiensis*
Cotton – (glyphosate tolerant): enolpyruvylshikimate-3-phosphate synthase gene from *Agrobacterium* sp.
Flax – (sulfonylurea tolerant): acetolactate synthase gene from *Arabidopsis*
Papaya – (virus resistant): coat protein gene of the papaya ringspot virus
Potato – (insect protection): cryIIIA gene from *Bacillus thuringiensis* (Bt) sp
Radicchio Rosso – (male sterile): barnase gene from *Bacillus amyloliquefaciens*
Rapeseed – (male sterile/fertility restorer): barnase gene and barstar gene from *B. amyloliquefaciens*
Soybean – (glyphosate tolerant): enolpyruvylshikimate-3-phosphate synthase gene from *Agrobacterium* sp.
Squash – (virus resistant): coat protein gene of watermelon mosaic virus 2 and zucchini yellow mosaic virus
Tomato – (modified fruit ripening): S-adenosylmethionine hydrolase gene from *E. coli* bacteriophage T3

Assessment

The Animal and Plant Health Inspection Service (APHIS) of the US Department of Agriculture (USDA) reviews approximately 1,000 applications each year from biotechnology companies that wish to field test new transgenic plants or to have a plant deregulated (NAS, 2002). Based on a review of the federal procedures, the National Academies' National Research Council (NRC) has recommended that the USDA should: 1) solicit greater public input, 2) enhance scientific peer review, 3) more clearly present the data and methods behind regulatory decisions, and 4) continue ecological testing and monitoring after transgenic plants have entered the marketplace (NRC, 2002).

APHIS approval for field-testing is granted through the "notification" process, where companies submit applications indicating that the plant meets general guidelines concerning unwanted environmental impacts. However, there is no public or independent scientific input during this process, and there is no limit to the acreage that can be planted during "testing" (NRC, 2002). Two concerns with pesticide producing plants are the harm to non-target organisms and the development of pest immunity to the pesticide. APHIS's treatment of these potential impacts was found to be superficial (NRC, 2002)

EPA regulates plant-incorporated proteins; that is, EPA regulates the pesticide protein and its genetic material, but not the GMO plant itself. In one review of *Bt* Cry1Ab Delta-endotoxin in corn, EPA (2000) determined that the "overall risk to a substantial number of individual non-target organisms in populations exposed to the levels of endotoxin found in plant tissue is anticipated by the Agency to be minimal during the duration of this conditional registration." In addition EPA found that there is no significant risk of gene capture and expression of any of the Cry endotoxins by wild or weedy relatives of corn. A summary of effects of *Bt* endotoxin on non-target organisms are listed in Table 1.

Table 1. Impacts on Non-target Organisms from *Bt* endotoxin (EPA, 2000).

SPECIES	**Dose**	**No Observed Effect Level (NOEL)**	**NOTES**
Honey Bee (larvae)	20 ppm	>20 ppm	Field corn tissues averaged approximately 6 ppm endotoxin Range 0.4-16.2 ppm

Honey Bee (adult)	20 ppm	< 20 ppm	
Parasitic Hymenopteran	20 ppm	> 20 ppm	
Green Lacewing	16.7 ppm	> 16.7 ppm	
Lady Beetles	20 ppm	> 20 ppm	
Northern Bobwhite Quail	2,000 mg/kg body weight	No effects observed	
Earthworms	200 ppm	14-day LC_{50} = >200 ppm	
Collembola	200 ppm	> 200 ppm	EPA requested a retest using leaf extract
Channel Catfish	Transgenic corn diet	No effects observed	
Aquatic Invertebrates	-	-	Studies on file at EPA demonstrate adverse effects on daphnids.
Mammals	-	-	No toxicity expected based on acute oral mouse study results.
Non-target Lepidopterans and Endangered Species	-	-	Field data on Bt microbrial sprays show a temporary reduction in lepidopteran (butterfly) populations.

In a more recent assessment of the impacts of Bt plant-incorporated protectants on non-target species, EPA concluded that the available information indicated a very low probability of risk to monarch butterflies in areas beyond the near edge of corn fields (EPA, 2001). However, there is a low probability of monarch larvae exposure to a toxic level of *Bt* corn pollen inside and near the edge of cornfields. In addition, the EPA indicated that additional data on the chronic risk of avian consumption of Bt corn may be needed, and *Bt* cotton isolation distances may need to be expanded in certain areas (e.g., Hawaii, Puerto Rico) where there are related cross compatible wild species that may be fed on by endangered insects (EPA, 2001).

The Ecological Society of America (2001) issued the following statement that concisely summarizes the ecological/environmental concerns with GMOs.

Genetically modified organisms (GMOs) have the potential to play a role in sustainable agriculture, forestry, aquaculture, and bioremediation. However, both deliberate and inadvertent releases of GMOs into the environment could also have negative ecological impacts under certain circumstances. For example, fast-growing transgenic salmon might jeopardize native fish populations, or altered viruses for biocontrol of insects may have unexpected effects on non-target populations. GMO risk evaluation should focus on the product, but should recognize that some GMOs can possess genuinely new characteristics that may require greater scrutiny than organisms produced by traditional techniques of plant and animal breeding. Since long-term ecological impacts of GMOs may be extremely difficult to predict or study prior to commercialization, ESA strongly recommends a cautious approach to releasing GMOs into the environment.

GMOs should be evaluated and used within the context of a scientifically based regulatory policy that encourages innovation without compromising sound environmental management. The process by which this occurs should be open to public scrutiny. Environmental risks associated with GMOs should be evaluated relative to appropriate risk reference scenarios, such as conventionally bred organisms, with due consideration of the ecology of the organism receiving the trait, the trait itself, and the environment into which the organism will be introduced.
Engineered organisms that may pose some risk and hence require scrutiny include cases where there is uncertainty about environmental effects. These could be cases where: there is little prior experience with the organismal trait and host combination;

an organism may persist without human intervention;
genetic exchange is possible between a transformed organism and unaltered organisms, or the trait confers an advantage to the GMO over native species in a given environment.
An assessment of environmental risk is needed to minimize the likelihood of negative ecological effects such as:
creating new or more vigorous pests and pathogens;
exacerbating the effects of existing pests through hybridization with related transgenic plants or animals;
harm to non-target species, such as soil organisms, non-pest insects, birds, and other animals;
disruptive effects on biotic communities; and
irreparable loss or changes in species diversity and genetic diversity within species.

In a review of the ecological risks and benefits of genetically engineered plants the following was concluded (Wolfenbarger & Phifer, 2000):

the risks and benefits of GMOs are not certain or universal; they may vary spatially and temporally on a case-by-case basis;
the capacity to predict ecological impacts is imprecise; uncertainty is increased by the inability to accurately predict impacts;
additional or unidentified benefits and risks may exist that current published data do not yet address;
the expected dramatic increase in the variety of GMOs may collectively represent an environmental risk, given the limitations of predicting negative effects; and
evaluation of potential environmental benefits will allow risk managers and decision-makers to balance these against the extent and irreversibility of any ecological change.

New Jersey

In 2000, NJ growers harvested 75,000 acres (10,050,000 bushels) of corn for grain, and 98,000 acres (3,920,000 bushels) of soybeans (NJDA, 2001). In 2001, the NJ harvest was 66,000 acres (7,392,000 bushels) of corn, and 101,000 acres (3,131,000 bushels) of soybeans (Table 1, USDA, 2002). National data is compiled on the amount of acres of GMO crops planted, however, according to the NJ Agricultural Statistics Service, there is no state-specific data compilation (NJASS, 2002). GMO crops are planted in New Jersey, however there is no state collected data on the acreage or percentage of these type of crops used in the state (NJASS, 2002). The extent of GMO use in NJ is unlikely to be greater than the national average figures which, in 2001, were 26% of the corn and 68% of the soybean acreage (USDA, 2002a). This provides only a crude estimate of the ecosystems or areas of the state that are potentially at risk from GMOs. In 2001, three counties had a total of more than 20,000 acres of corn/soybean crops planted: Salem (40,500 acres), Burlington (32,400 acres), and Warren (23,500 acres). Five other counties had more than 10,000 acres of these crops planted in 2001: Cumberland (15,700 acres), Gloucester (13,300 acres), Hunterdon (12,400 acres), Middlesex (12,300 acres) and Monmouth (10,500 acres).

If research identifies adverse ecological impacts from GMOs, data on the extent of GMO use in NJ crops and other organisms should be collected. Potentially impacted areas/ecosystems could then be identified for study.

Table 2. New Jersey 2001 Crop Statistics for Corn and Soybean (USDA, 2002)

Commodity	**County**	**Planted (acres)**	**Harvested (acres)**	**Yield (BU/acre)**	**Production (BU)**
CORN (for grain)	Atlantic	600	500	78	39000
	Burlington	8700	7700	106.5	820000
	Cumberland	3600	3000	118	354000
	Gloucester	3800	2600	75	195000

	Hunterdon	7300	6600	130.3	860000
	Mercer	3500	3200	95	304000
	Middlesex	4000	3600	112.2	404000
	Monmouth	3300	3000	112.3	337000
	Morris	1000	900	100	90000
	Ocean	500	400	95	38000
	Salem	16800	13100	105.5	1382000
	Somerset	2800	2300	80.9	186000
	Sussex	4900	3300	91.2	301000
	Warren	18700	15400	132.5	2040000
	State Total	80000	66000	112	7392000
SOYBEANS	Burlington	23700	23400	30	702000
	Cumberland	12100	11800	32	378000
	Gloucester	9500	9400	22.8	214000
	Hunterdon	5100	5000	35	175000
	Mercer	6300	6200	32.6	202000
	Middlesex	8300	8100	30.9	250000
	Monmouth	7200	7000	33.1	232000
	Salem	23700	23200	30	696000
	Somerset	1600	1500	29.3	44000
	Warren	4800	4800	45.8	220000
	State Total	103000	101000	31	3131000

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Issue: Green/Red Tide
Author: Mary Downes-Gastrich
Version: 05/02/00

New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Stressor:

Green/Red Tides

and other species (Harmful Algal Blooms)

Risk: Low to Medium risk but possibly greater risk later (if harmful algal blooms occur with greater frequency) in specific marine ecosystems or watersheds

Severity: 3

Confidence/Uncertainty Score: Medium to High Confidence (Low to medium uncertainty)

Trend: (0) Same, no expected increase in incidence of these types of harmful algal blooms

Catastrophic Potential: Low

A recent issue paper, "Harmful Algal Blooms in the waters of New Jersey" has been drafted that summarizes the impacts of harmful algal blooms in New Jersey coastal waters (Gastrich, 2000) and NJDEP has annual summary reports of phytoplankton blooms including blooms harmful to human health (NJDEP, 2000). Harmful Algal Blooms (HABs) are an increasing phenomena throughout the world which may have been responsible for an estimated one billion dollars in economic loses during the last decade (U.S. Environmental Protection Agency, 1999, Public Law, P.L., 105-383). HABs can be responsible for fish kills, deaths of marine mammals, beach and shellfish bed closures, various human health effects and public avoidance of seafood (U.S. Environmental Protection Agency, Public Law. 105-383).

Recently, the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) was signed into law on November 13, 1998 becoming Public Law 105-383. The Act recognizes that many of the coastal areas throughout the world are suffering from harmful algal blooms and hypoxia each year, threatening coastal ecosystems and endangering human health. The Act recognizes that occurrence of HABs include red tides in the Gulf of Mexico and Southeast; brown tides in New York, Texas (and now New Jersey), Ciguatera fish poisoning in Hawaii, Florida, Puerto Rico, and the U.S. Virgin Islands, and shellfish poisonings in the Gulf of Maine, the Pacific Northwest and the Gulf of Alaska (Title VI – Harmful Algal Blooms and Hypoxia). The Act calls for the following:
The establishment of an inter-agency task force on Harmful Algal blooms (HABs) and hypoxia
A national assessment on harmful algal blooms – draft available June 1999
A national assessment on hypoxia
An assessment and Plan for hypoxia in the Gulf of Mexico

There is a widely held supposition that algal blooms are a result of nutrient loadings. However, a recent national assessment of harmful algal blooms (draft, HABHRCA 1999) concludes that, except for a few cases where there is some evidence to support this, the majority of U.S. HABs cannot be tied to anthropogenic nutrient loading, but to a combination of regional circulation patterns coupled to life histories of the species. While there seems to be no universal relationships between nutrient enrichment and the occurrence of HABs, at least three specific algal species may bloom as a result of nutrient inputs: *Pfiesteria piscicida* (a dinoflagellate toxic to humans and fish), *Pseudonitzschia* (several toxic species of diatoms associated with Amnesic Shellfish Poisoning), and *Heterosigma (confused with Olisthodiscus sp.* which is a Raphidophycean golden-type alga associated with fish kills at fish pen aquaculture operations). More commonly associated with the development of HABs are local circulation patterns, long periods of low water flow, water column stratification, and reduced mixing – conditions that are often associated with long flushing rates and long residence times for water. Such conditions are found as in the shallow Peconic estuaries in Eastern Long Island (HABHRCA, 1999) and possibly, Barnegat Bay in New Jersey.

There have been chronic red tide blooms of various species in the Hudson-Raritan Estuary and New Jersey coastal waters for over three decades (NJ Annual Phytoplankton Report, 1998). These blooms include the dinoflagellate species in New Jersey coastal waters (e.g*., Ceratium tripos, Prorocentrum spp. Ceratium tripos, Cochlodinium heterolobatum, Masartia (=Katodinium) rotundatum, Olisthodiscus luteus, Prorocentrum micans (P. redfieldi, P. lima)).* Harmful algal blooms may contribute to hypoxia or other negative ecological impacts, but it is important to point out that there are few cases on record of acute human toxicity from phytoplankton in New Jersey waters with some exceptions of moderate discomfort and/or illness reported from specific blooms (NJDEP Annual Summary, 1998). It is also important to keep in mind that many incidents of human health complaints (e.g., bather complaints) are not reported and there are few systematic cause/effect studies conducted to assess the ecological consequences of algal blooms.

While some harmful algal blooms in other areas of the nation have resulted in severe human illness, there are no reports of such algal blooms occurring in New Jersey with the exception of moderate illness and/or bather discomfort caused by the green tide organism, *Gyrodinium cf aureolum* (and red tides of *Prorocentrum, Massartia, and Olisthodiscus* spp*.)*. The green tide appeared as a greenish discoloration of the near shore coastal waters from Ocean City to Atlantic City during the summers of 1984-85. There were reports from swimmers of skin reactions, respiratory problems, nausea, sore throat, eye irritation, fatigue, dizziness, fever and lung congestion as a result of exposure to the bloom (U.S. Environmental Protection Agency Region 2, October 1986).

Human illness from consumption of toxic shellfish are caused by different species of toxic algae which occur in coastal waters of the US and other areas of the world and include: Paralytic Shellfish Poisoning (PSP) (*Alexandrium spp., Gymnodinium catenatum, Pyrodinium bahamense)* (National Office for Marine Biotoxins and Harmful Algal Blooms, 1999), Amnesic Shellfish Poisoning (ASP) (*Pseudonitzschia* sp.), Ciguatera fish poisoning (*Gambierdiscus toxicus, Prorocentrum* spp., *Ostreopsis* spp., *Coolia monotis*, *Thecadinium* spp. and *Amphidinium carterae),* Diarrhetic Shellfish Poisoning (*Dinophysis* sp.), and Neurotoxic Shellfish Poisoning (*Gymnodinium breve*) (Cohn et al. 1988; NJDEP Annual Summary 1998; Woods hole Oceanographic Institute 1999). While *Pseudonitzschia* spp. (closely associated with Amnesic Shellfish Poisoning in humans) has been abundant in NJ coastal waters and near shore waters, especially during the fall and winter months, there are no reported cases of ASP in New Jersey (NJDEP Annual Phytoplankton Reports, 1998).

There are no reported occurrences of the dinoflagellate *Gymnodinium breve* in NJ coastal waters, but it is associated with Ciguatera fish poisoning and Neurotoxic Shellfish Poisoning in tropical/subtropical waters (NJ Annual Phytoplankton Reports, 1998). While the dinoflagellates, *Scripsiella trochoidea* and *P. brevipes,* have been abundant in NJ coastal waters, they have not been related to toxicity in NJ waters (NJ Phytoplankton Reports, 1998).

Phytoflagellate blooms caused by the dinoflagellate species, *Massartia rotundata (=Katodinium)* and *Prorocentrum micans* and the golden alga, *Olisthodiscus luteus,* were dominant blooms from 1962-1976 in New Jersey coastal waters (including Raritan Bay) from June to September (Mahoney and McLaughlin, 1977). These species were presumed benign, but there were reports of adverse effects on biological and recreational uses in the area, including respiratory discomfort among bathers (as reported in Mahoney and McLaughlin, 1977).

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New Jersey Comparative Risk Project
Ecological Quality Technical Work Group
Stressor-Specific Risk Assessment

Stressor:
Greenhouse Gases

Issue Summary: Despite some lingering debate about the impacts of greenhouse gases (GHGs) on global climate change, the international scientific consensus, through the Intergovernmental Panel on Climate Change (IPCC) is that the primary cause of excess global climate warming during the last century is the anthropogenic input of GHGs in the atmosphere (NJDEP, 1999).   Global warming would result in sea level rise which could have a very significant impact on New Jersey's coastal resources including aquatic and terrestrial ecosystems. However, even with predictions developed from models, there appears to be a medium to high level of uncertainty concerning whether global warming is going to continue.   However, New Jersey has addressed climate change through various documents (e.g., NJ Coastal Alliance and Coastal Plan) and taken several actions which address the reduction in greenhouse gas emissions including: 1) NJDEP's "NJ Sustainability Greenhouse Gas Action Plan"; 2) establishment of the NJDEP Global Change Workgroup; 3) NJDEP's Commissioner's Administrative Order on Climate Change; and 4) development of goals and indicators for climate change in the National Environmental Performance Partnership System (NEPPS); and 5) Letter of Intent with the Netherlands Environmental Ministry (outlines areas where the two parties will work together to address issues related to global climate change).

Severity: Medium-Low for aquatic systems; low for terrestrial systems.

Uncertainty: High

Introduction
There is consensus among many leading scientists, participating through the Intergovernmental Panel on Climate Change (IPCC), that global climate change (GCC) is recognized as potentially one of the most significant environmental threats facing the world today.

Global Warming
Climate change can significantly alter the natural environment and is attributed mainly to anthropogenic activities which alter the chemical composition of the atmosphere through a buildup of heat trapping greenhouse gases (GHGs) (e.g., carbon dioxide, methane, nitrous oxide and chlorofluorocarbons) (USEPA, 1997). The burning of fossil fuels (e.g., coal, oil and natural gas) for energy is the primary source of emissions (USEPA, 1997). Greenhouse gases (GHGs) are chemical compounds that absorb infrared radiation in the form of heat, preventing the venting of this energy into space (NJDEP, 1999).

A. Increased Temperatures
USEPA (1997) reports that global mean surface temperatures have increased 0.6-1.2^{o}F since the late 19th century – or generally, about one degree in the last century. The last twenty years have seen an unprecedented rise in surface temperatures and the nine warmest years in this century have occurred in the last 14 yrs. (USEPA, 1997). It is generally accepted that global warming is to due increased emissions of GHGs. Impacts of global warming include sea level rise (SLR) and an increase and intensity of tropical storms (especially in the warmer oceans) (Mahlman, 1997). The coupling of rising sea levels and storms could lead to greatly increased damages to coastal areas. These impacts could be significant because of the extent of New Jersey's shoreline and coastal areas.

B. Thinning of polar ice caps
Thinning of polar ice caps is linked to the global warming issue. There is preliminary evidence that the Arctic ice cover has continued to become thinner (> 1 meter) in some regions (within the central Arctic Ocean) during the 1990s but whether these changes are due to changes in arctic heat fluxes or precipitation/snow cover or advective processes

(e.g., increased ice export) is not clear (Rothrock et al., 1999). There is not currently a good temporal record of ice cover over the Arctic Ocean (Rothrock et al., 1999). Furthermore, whether the ice volume has reach a minimum over several decades or whether it will continue to decline signals the need to address this issue in an overall theory of climate variability (Rothrock et al., 1999).

C. Predicting Future Climatic Changes in New Jersey

At the global level, for a given concentration of GHG, the resulting increase in the atmosphere's heat-trapping ability can be predicted with precision, but the resulting impact on climate is more uncertain (USEPA 1997). Recent model calculations suggest that the global surface temperature could increase an average of 1.6-3^{o}F by 2100, with significant regional variation (USEPA 1997). This temperature change would be greater than recent natural fluctuations in temperature and would occur much faster than any known changes in the last 10,000 yrs (USEPA 1997). Models suggest that the frequency of intense rainfall as well as marked decrease in soil moisture over some mid-continental regions during the summer. Sea level rise is projected to increase by 6-38 inches by 2100 (USEPA 1997).

However, at the regional level (in NJ), calculations of regional climate change are not as reliable as global ones (USEPA 1997). Over the last century, the average temperature in New Brunswick, NJ has increased from 50.4^{o}F (1889-1918 average) to 52.2^{o}F (1966-1995 average) and precipitation is some locations in the state has increased by 5-10% (USEPA 1997).

Based on projections of the Intergovernmental Panel on Climate Change and the UK Hadley Centre's climate model (HADCM2), by 2100, temperatures in NJ could increase about 4^{O}F with increases in precipitation by 10-20% (UK Climate Change Programme Consultation Paper. 1998). Over the last century, the average temperature in New Brunswick, NJ, increased by 5-10%. Decreases in stream flow, due to evaporation in warmer climate, could result in lower river flow, lower lake levels in summer, and possibly, reduced groundwater levels (USEPA, 1997). This, in turn, may affect the quality of potable water. Approximately ½ of the state's potable water comes from streams and rivers in the coastal areas (e.g., Delaware, Raritan and Passaic rivers and others)(USEPA, 1997); the other ½ comes from groundwater. The mean annual flow of the Delaware River at Trenton could decrease about 15% if average temperatures warm 4.5^{o}F and precipitation is unchanged. In the northern part of the state, urbanization has lowered water quality and increased flooding in small rivers and streams. Reduced flows in summer, would further decline water quality (USEPA 1997).

D. Impacts of Global Warming in Coastal New Jersey

Global warming may pose risks to human health and to terrestrial and aquatic ecosystems (USEPA 1997). A recent report of the consequences of climate change in the states comprising the Mid-Atlantic Region (MAR), indicates that the MAR can expect both positive and negative impacts from climate change. Although the benefits are fewer and not large compared to potential damages, the distribution of these impacts is an issue that has ecological, human health, and socioeconomic implications (USEPA 1999). This assessment suggests that while the economy will be resilient to projected climate change, climate change poses diverse and potentially large risks to the region's ecosystems. It seems most certain that there is the potential for substantial damage to the coastal zone's structures, wetlands, estuaries, and to water supplies because of salt-water intrusion (USEPA, 1999). There seems to be moderate certainty that there is a potential for very large negative impacts on MAR biodiversity. Ecological impacts could be among the region's largest impacts but they are very uncertain (USEPA, 1999). The increasing trend of urbanization in New Jersey coastal areas could also present problems of urban warming in these areas, which needs to be evaluated.

E. Impacts of Sea Level Rise

1) Predicted Changes in Coastal Areas of New Jersey

Sea level rise in coastal areas could increase the vulnerability of coastal areas to storms and associated flooding and other impacts (flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater intrusion of drinking water, and decreased longevity of low-lying roads, causeways and bridges) (USEPA 1997).

Sea level rise in New Jersey was measured at approximately 3.8 mm/yr (0.15 in/yr at Atlantic City) using tide gauges – this represents about twice the world rate which is estimated at 1-2 mm/yr over the past 80 yrs (USGS, 1998). Sea level rise has been predicted to rise in NJ coastal areas by about 15 inches per century and it is likely to rise another 27 inches by the year 2100 (USEPA, 1997). New Jersey has approximately 130 miles of coastline which would be vulnerable to erosion and flooding if sea level rise were to occur with increasing storms (USEPA, 1997). The narrow barrier islands, low-lying salt marshes and tidal flats which comprise the New Jersey coastline are particularly vulnerable (USEPA, 1997). Rising seas could cause extensive damage to the State's high-density coastal real estate and recreational beaches. In addition, it would flood many acres of coastal salt marshes and tidal flats, which now provide flood protection, water quality benefits, and habitat for living resources (USEPA 1997). Cost estimates of protecting Long Beach Island, NJ, with seawalls and more sand, from a 1-3 foot increase in sea level rise over the next century are $100-500 million.

2) Predicted Changes in Water Resources in New Jersey
Changes in stream flow, due to climate changes, may intensify changes in precipitation (USEPA 1997). If streamflow and lake levels drop due to a warmer climate, thereby producing lower river flows, groundwater could also be reduced. This could produce problems with adequate drinking water supply. As a result of decreased streamflow, due to increased evaporation accompanying warmer temperatures, the mean annual flow of the Delaware River at Trenton could decrease about 15% if average temperatures warm 4.5^{o}F and precipitation remains unchanged (USEPA 1997).

The effects of global climate change may affect water quality by altering source-delivery rates of pollutants to various environments. Specifically, global climate change is expected to enhance the remobilization and bioaccumulation of mercury (Nriagu, 1999). Atmospheric deposition appears to be the major source of mercury to temperate lakes (Sorenson et al. 1990) and anthropogenic activities have changed the natural biogeochemical cycle of mercury in many ecosystems (Nriagu, 1999).

In addition, current industrial emissions of mercury from industrial sources in North America are believed to be comparable to the flux from natural processes (sources) and global climate change is expected to change this ratio (Nriagu, 1999). Global climate change may also change the current deposition pattern and can result in further dispersion of already deposited mercury. A number of sites in North America are heavily contaminated with mercury (including abandoned gold and silver mines) and abandoned chlor-alkali plants and a change in climate may lead to increased exhalation of mercury from these so-called "chemical time bombs" (Nriagu, 1999).

Global climate change can alter the current deposition pattern for atmospheric mercury in many parts of the world and trigger an increase in rates of biogenic production and release of volatile mercury compounds (e.g., methylated compounds which are most readily absorbed by fish) (Nriagu, 1999). Increased remobilization of previously deposited mercury may convert from a sink to an area source. Global climate change influences the production of dissolved organic carbon and water temperature which in turn, will influence the bioaccumulation of mercury by fish (Nriagu, 1999). Extensive flooding of coastal areas would have a significant effect on the mercury cycle by increasing the efficiency and rates of mercury methylation and the levels in water and biota (Nriagu, 1999). The downstream effects of the flooded areas may expose a fisheries to mercury contamination (Nriagu, 1999). Food chain structures in temperate lakes tend to be non-linear so that small changes due to climate may results in rapid and severe changes in the methylation of de-methylation of mercury (Nriagu, 1999).

3) Impacts to Forests and Ecosystems in New Jersey
The extent and density of forested areas in New Jersey could change little or decline by as much as 10-20% with changes in climate (USEPA 1997). Wildfires would probably increase (USEPA 1997). The composition of the forests could change with different species (USEPA 1997). The southern pines and oak mixes, currently found in southern New Jersey, could spread northward and replace the hardwood forests in northern New Jersey (USEPA 1997).

Coastal wetland ecosystems would be most vulnerable to climate change. Approximately 19% of the State's land surface are represented by a wetland (Tiner 1985). Of the 31.6% of the State's estuarine wetlands, 72% was emergent wetland consisting of salt and brackish marsh (Tiner 1985). Deepwater habitat acreage in New Jersey totaled 412,949 acres, excluding marine waters, and was represented by estuarine or brackish tidal water of bays and coastal rivers (Tiner 1985). All coastal counties have wetlands but Cape May and Atlantic Counties had a greater percentage of wetlands than any other county (Tiner 1985). Other coastal areas, such as the Pine Barrens, which cover approximately 1 million acres of the Outer Coastal Plain in New Jersey, would also be vulnerable (USEPA 1997).

F. Emission Control and Concentrations of Greenhouse Gases

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The international Intergovernmental Panel on Climate Change, predicts that if no action were taken to limit greenhouse gas emissions, temperatures would rise in the range of 1-3.5^{0}C by the end of the century. This would be a faster rate of warming than at any time since the end of the last ice age, 10,000 yrs ago (UK Climate Change Program, 1998). If the pattern of the world's weather changes, this would increase the frequency and intensity of heat waves, floods, droughts and storms. Sea levels will rise between 15-95 cm (UK Climate Change Program, 1998). The NJDEP has developed a GHG Action Plan that identifies the major sources of GHGs by source and sector in 1990. More than 80% of the GHGs in NJ results from the combustion of fossil fuel and approximately 6% comes from methane in landfills (NJDEP, 1999). Emissions of U.S. GHGs in 1998 increased by 0.2% compared with 1997, the lowest annual growth rate since the recession of 1991 (Energy Information Agency, 1999).

Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased nearly 30%. These increases are expected to result in 1) an increase in the amount of UV-B radiation reaching the earth's surface; 2) a change (increase) in temperature of the atmosphere and earth's surface, and 3) a change in the hydrological regime, especially catastrophic weather incidents (e.g., floods, storms, and droughts)(Nriagu, 1999).

GCC poses risks to human health (e.g., higher temperatures and increased heat waves may increase heat-related illnesses) and to terrestrial and aquatic ecosystems (USEPA, 1997). Most of the world's coastal areas, which are the most populated, may be negatively impacted (UK Climate Change Program, 1998). Economic costs could be significant and the potential for dislocation of human society is enormous (UK Climate Change Program, 1998). Natural habitats could be lost and biodiversity would be greatly reduced. These threats are particularly important to New Jersey.
The most important ecosystems in New Jersey that would be vulnerable to climate change are the coastal wetlands and the forested Pine Barrens.

Information and data are available on agency websites:
EPA: www.epa.gov/globalwarming
IPPC: www.ipcc.ch
NOAA: http://www.ncdc.noaa/gov/ol/climate/research/cag3/cag3.html

There is a small minority of scientists that are skeptical about global warming trends as well as the potential causes, such as greenhouse gas warming, and subsequent effects, such as sea level rise (D'Aleo, 2001). This minority has several hypotheses, other than greenhouse gases for global warming that include: 1) urban "heat-island effect' warming; 2) solar sunspot cycles; 3 oceanic processes (e.g., thermohaline circulations, etc); 4) a combination of solar cycles and oceanic processes; and 5) local factors. While analysis of satellite and weather balloon data show a slight cooling of the lower atmosphere in the last two decades (D'Aleo, 2001), there is some uncertainty as to whether this trend will continue.

In conclusion, continuing data analysis is needed on historic and current records with respect to global warming.

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Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		Could have adverse affect on structure and function of coastal ecosystems. Could affect terrestrial systems.
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)		It could be possible in the future

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Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted		While all coastal areas would be affected, (10-25%) of the state, freshwater systems may also be affected. Portions of terrestrial ecosystems may also be impacted.
	Total	
Assessment of uncertainties in this assessment (H,M,L) and brief description	High because it is not known whether global warming will continue.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	High potential for change in risk assessment given additional data analysis.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	+ = Regardless of whether the stressor becomes significant, management actions that can be taken to minimize shoreline damage due to storms or continuing SLR would include: 1) education/outreach to municipalities on sea level rise at this point and 2) limiting development in barrier islands and low-lying coastal areas would minimize impacts.	
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	L: Potential for short-term catastrophic impacts are expected to be low. Long-term impacts could be High for the NJ shore, if global warming and SLR increases, due mainly to increased and more intense storms. See write-up above.	
Link to other Work Groups (e.g., socioeconomic impacts)	Socioeconomic impacts of global warming and sea level rise are significant. There are also human health impacts of climate change due to increasing temperatures, floods, changes in weather patterns (e.g., violent storms, etc.)	
Extent to which threat is currently regulated or otherwise managed	According to the Regional Plan Association recent report, based on a survey, entitled, "Government Actions on climate change in the NY-NJ-CT metropolitan region (RPA 1998), the NJDEP was one of the few government respondents which are taking active steps to prepare for climate change. For example, the NJDEP established the NJ Global Climate change Work Group to develop a State Action Plan and a Greenhouse Gas Emissions Trading Bank in conjunction with other NJ state and local agencies and business and nongovernmental representatives (RPA, 1998). The NJDEP has a coastal management plan for the state and there is a State Development Redevelopment Plan. However, coastal planning within NJDEP is undergoing a reassessment of the previous 20-yr coastal plan. The new planning effort will identify relevant goals, indicators, and actions. Currently, the coastal area is managed through the state's Coastal Zone Management Program.	
Barriers to restoration	Increased development in low-lying shore areas and barrier islands.	

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New Jersey Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Habitat Fragmentation**
Description of stressor	Subdivision of continuous habitats into smaller patches by development, transportation corridors and other human activities. Habitat fragmentation is a frequent consequence of habitat loss, but the effects of fragmentation differ from effects of loss per se.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	Biological integrity Habitat fragmentation results in changes in the assemblages of species found in remaining fragments: Fragmentation results in the creation of “edge habitat” along the fragment border, which differs in microclimate and species composition from the original habitat (reviewed in Saunders et al. 1991). Fragmentation increases the variability of ecological communities over time, increasing the turnover rate of species in communities (Boulinier et al. 1998). Habitat fragmentation results in increased susceptibility of ecological communities to invasion by exotic (non-native) species (reviewed in Saunders et al. 1991). Roads act as corridors for exotic species invasion of adjacent habitat fragments (Parendes and Jones 2000). Roads that fragment habitats can block the movement of animals. Traffic may cause animals to avoid the area of the fragment adjoining the road, further reducing the suitable habitat of the fragment (Trombulak and Frissell 2000). Biodiversity Habitat fragmentation results in a reduction in biodiversity, with the number of species declining as patch size declines (Wilcox and Murphy 1985; Newmark 1986), although, in the short term, species number may not change and may even increase because of invasion by exotic or generalist species (reviewed in Debinski and Holt 2000). Reduction in the area of habitat for animals in the remaining fragment results in local extinctions, particularly in species with large territories and in species dependent on native vegetation (reviewed in Saunders et al. 1991). Fragmentation may result in the loss of critical, or “keystone” species that have disproportionately large ecosystem effects for their abundance, including predators with large area requirements. Loss of even a single keystone species could lead to extinctions of many other species and the collapse of entire food webs through effects at the level of the ecological community (Wilcox and Murphy 1985).
	Isolation of fragments from each other by altered landscape impairs exchange of individual organisms and their genes among fragments, and may prevent recolonization from other areas of fragments in which local populations have gone extinct (reviewed in Saunders et al. 1991).

	Fragmentation decreases the distance that forest interior species are able to travel from the forest edge, making them more likely to be extirpated by predators and parasites that live in bordering habitats (Robinson et al. 1995). Habitat/ecosystem health Habitat fragmentation acts as a stress on ecosystems that may make them more susceptible to – and less able to recover from – other stressors (e.g., Chapin et al. 1997; Rapport and Whitford 1999). Fragmentation results initially in crowding of remaining animals, followed by a reduction in their abundance (reviewed in Debinski and Holt 2000). Habitat fragmentation may result in increased susceptibility of agricultural land to pests due to reduction in natural predators (Kruess and Tscharntke 1994). Ecosystem function Habitat fragmentation may reduce the ability of remaining fragments to support normal ecosystem functions. Loss of important species from fragments may disrupt ecosystem functions in ways that are difficult to predict (Wilcox and Murphy 1985). Increased sunlight penetration increases temperatures at the edge of habitat fragments, affecting microorganisms living in soil and altering nutrient cycling. Increased sunlight penetration also restricts the edge of the habitat fragments to plant species that are tolerant of higher light levels (reviewed in Saunders et al. 1991). Removal of surrounding habitat increases exposure of remnant habitat fragments to wind, damaging trees, decreasing moisture levels and increasing transfer of insects, disease organisms and seeds of exotic plant species into the fragment (reviewed in Saunders et al. 1991). Habitat fragmentation modifies various components of the hydrological cycle, changing rates of erosion and evapotranspiration (water evaporated from plants), and water table and salinity levels (reviewed in Saunders et al. 1991).
Key impacts selected (critical ecological effects)	Biological integrity, Biodiversity and Habitat/ecosystem health: impacts as listed above. Insufficient New Jersey-specific information is available to evaluate Ecosystem function impacts beyond the general statement of impacts given above.
Exposure Assessment	
Exposure routes and pathways considered	Fragmentation resulting from land conversion from forest/rural/agricultural to urban/suburban. Habitat subdivision by roads. Interruption of streams and rivers by dams, roadways and rail corridors.
Population(s)/ecosystem(s) exposed statewide	All terrestrial animal and plant populations and ecosystems statewide that are found on undeveloped, unprotected land. Freshwater ecosystems in waterways exposed to interruption by dams and transportation corridors. Particularly high exposure of unprotected forest ecosystems statewide. Erosion effects (e.g., siltation) may expose freshwater and marine ecosystems to impacts of habitat fragmentation.

Quantification of exposure levels statewide	Spatial: As of 1995, the areas of different habitat types in New Jersey were as presented in the following table. Differences in values reported by the two sources (BGIA 2000 and Lathrop 2000) are due to differences in their methodologies and land classification schemes. BGIA (2000) Lathrop (2000) Land Use/Land Cover Level 1 Category Area (acres) Land Cover Level 1 Category Area (acres) Urban 1,342,525 Developed 1,427,310 Agriculture 659,017 Cult/grass 883,590 Forest 1,602,577 Upland Forest 1,421,060 Barren Land 57,971

Bare Land
45,530

Wetlands
1,033,470

Coastal wetland
201,570

Inland wetland
737,010

Water
788,405

Water
514,960

Unconsolidated shore
45,880

Due to methodological and land-classification differences, USDAFS (2000) reports a greater area of total forested land in New Jersey than either BGIA (2000) or Lathrop (2000; see previous table): 1,991,000 acres. USDAFS (2000) is of particular value in the present context for classifying ownership of forested land, as presented in the following table (1997 values). Note that the great majority of all forested land in New Jersey is privately owned, and thus more difficult to protect than if it were owned by government.

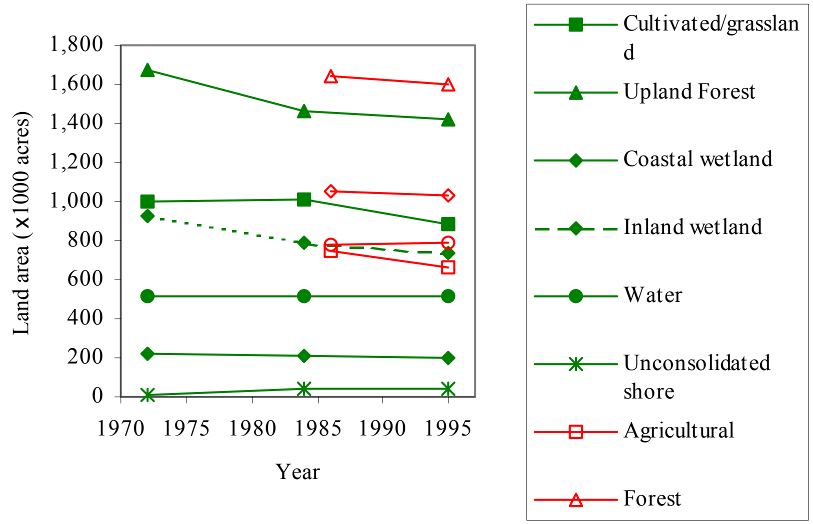
Federal
State of NJ
County and municipality
Total public
Private

Area (× 1000 acres)
96
382
127
605
1,386

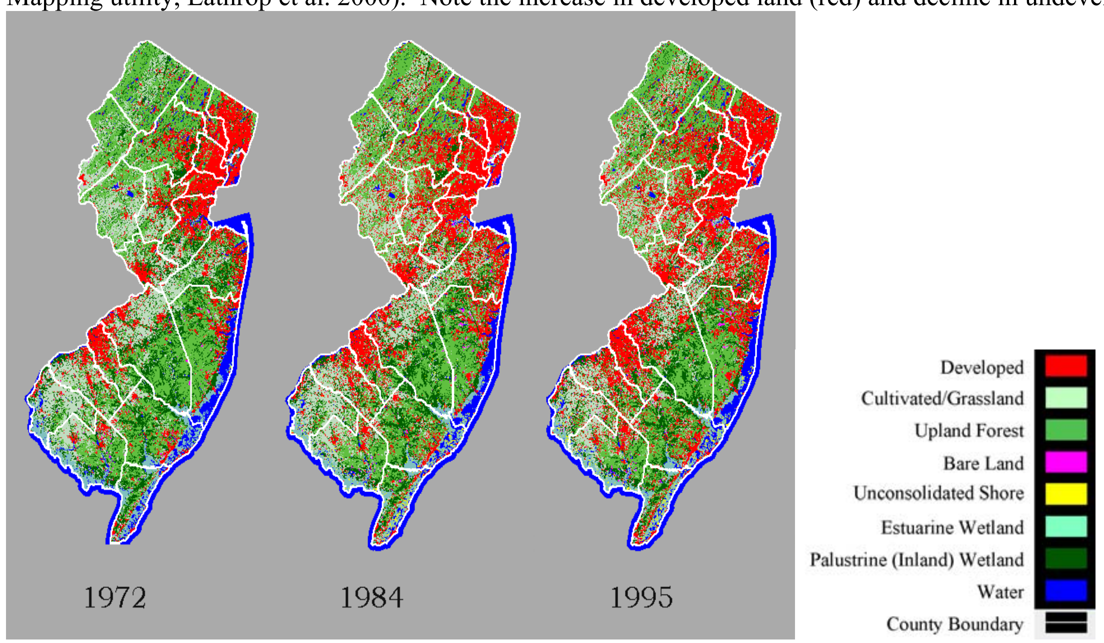
Percentage of total forested land
4.8
19.2
6.4
30.4
69.6

Most federally owned land in New Jersey is under some form of protection from habitat loss, but the vast majority of land in New Jersey is not federally owned. Total nonfederal land in New Jersey, excluding water areas, is 4,537,100 acres. This is 87% of the total area of New Jersey, and 97% of the total non-water area of New Jersey. Of this amount, 1,848,900 acres (41%) is developed land (1997 values from NRI 1997). Undeveloped nonfederal land is 2,688,200 acres. This is 57% of the total non-water area of New Jersey, and 59% of the total nonfederal land area (1997 values; NRI 1997).
Regions of particular importance because they still contain large tracts of critical wildlife habitat but are vulnerable to loss include the New Jersey Pinelands (1.1 million acres; NJPC 2000a) and the New Jersey Highlands. The Highlands are 640, 478 acres, of which 334,871 acres are classified under the State Planning Area system as Environmentally Sensitive, and 158,104 acres are classified as Rural and Rural/Environmentally Sensitive (NJOSP 1999a).

Tempor al:
The following graph presents the decline from 1972 to 1995 in the areas of specific undeveloped habitat types. Differences between the two sources (BGIA 2000 and Lathrop 2000) are due to differences in their methodologies and land classification schemes. Both sources report qualitatively similar trends (open, red symbols = BGIA 2000; solid, green symbols = Lathrop 2000).



The following three maps depict the change in land cover in New Jersey from 1972 to 1995 (maps generated with Interactive Mapping utility, Lathrop et al. 2000). Note the increase in developed land (red) and decline in undeveloped habitat types.



Specific population(s) at increased risk	Fragmentation is likely to have negative effects on a wide range of organisms in New Jersey. Impacts are best documented for the following groups, but this list should not be considered exhaustive. Birds The diversity of bird communities in the mid-Atlantic region decreases as the proportion of land that is urban increases (Cam et al. 2000). The number of different bird species in mixed-oak forests in New Jersey decreases with decreasing forest patch size (Galli et al. 1976). Variability in bird species diversity over time also increases with decreasing forest patch size (Boulinier et al. 1998). The abundance of 26 different forest breeding bird species in mid-Atlantic states declines with decreasing forest patch area (Robbins et al. 1989; Boulinier et al. 1998). Increasing forest fragmentation reduces the abundance of tanagers (birds in the genus Piranga), and this effect is higher in the Atlantic Coast region, including the State of New Jersey, than in forests further northeast (Rosenberg et al. 1999). Diversity of hawk and owl species in New Jersey decreases with decreasing forest size (Bosakowski and Smith 1997). Red-shouldered hawks (Buteo lineatus; State Threatened), barred owls (Strix varia; State Threatened) and northern goshawks (Accipiter gentilis; State Endangered) avoid areas fragmented by urbanization (Bosakowski and Smith 1997). Forest fragmentation in New Jersey poses a threat to the disturbance-intolerant barred owl, which requires mature and old-growth forest. Fragmentation brings the species into closer contact with the disturbance-tolerant great horned owl (Bubo virginianus), which preys on barred owl adults and young and may compete with barred owls for prey (Laidig and Dobkin 1995). The parasitic brown-headed cowbird (Molothrus ater) decreases the reproductive success of forest-nesting birds by laying its eggs in the nests of these birds, which then raise the cowbird hatchlings at the expense of their own offspring. Brown-headed cowbird abundance increases with increasing forest fragmentation (Robinson et al. 1995). Brown-headed cowbirds are more abundant than 20 of 21 forest-interior neotropical migrant bird species in southern New Jersey (Rich et al. 1994), and cowbird impact may be higher in New Jersey than in some other areas of the eastern United States, including Pennsylvania (Yahner 1995). Predation on nests of forest birds by mammals and other birds also increases with increasing forest fragmentation (Robinson et al. 1995). Amphibians Because they live in bodies of water that may be isolated from one another, amphibians are severely impacted by habitat fragmentation, especially fragmentation by roads which restrict travel from one pond to another (Gibbs 1998; Vos and Chardon 1998). Fragmentation alters amphibian communities. Adults of frog species that are not normally found in intact habitats of the New Jersey Pinelands are able to enter the Pinelands at the border between habitat fragments and land disturbed by human activities (Bunnell and Zampella 1999). Bullfrogs (Rana catesbiana) are not native to the Pinelands but are found in fragmented Pinelands habitat next to human-altered land. Native Pine Barrens treefrogs (Hyla andersonii), a State Endangered species, are not found in areas occupied by bullfrogs, indicating that bullfrogs may prey on or compete with this species, thus altering native frog diversity (Zampella and Bunnell 2000). Freshwater animals and plants Dams that fragment waterways change the flow, temperature and nutrient content required by aquatic organisms, and are a physical barrier to dispersal (Master et al. 1998). Damming and channeling of rivers make habitats unsuitable for freshwater mussels because siltation and low oxygen levels are created above the dam, and water temperatures and levels are changed below the dam (Porter and Hill 1998).

	Crops (potential impact) Agricultural crops may be affected by fragmentation because habitat fragmentation impacts natural predators of pests such as parasitic wasps more than plant-eating pests like weevils (Kruess and Tscharntke 1994).
Quantification of exposure levels to population(s) at increased risk	See above, under "Quantification of exposure levels statewide", for areas of habitat types in which particular populations are exposed (e.g., birds are exposed primarily in forested land; aquatic organisms are exposed primarily in wetlands and bodies of water; agricultural habitats are exposed primarily in cultivated land).
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	Quantitative dose assessment Open spaces in New Jersey are being fragmented, with large habitat patches being broken into several smaller ones (Lathrop 2000). The following table depicts the increase in the number of small forest tracts and the corresponding decrease in intermediately large forest tracts in New Jersey between 1984 and 1995 (after Table 6 in Lathrop 2000; forest tracts are defined as contiguous forest not subdivided by highways; tracts smaller than 2.5 acres are excluded from this analysis): Forest tract area category (acres) Number of tracts in area category Area of forest tracts in area category (acres) Proportion of total area of forest tracts in area category (%) 1984 1995 1984 1995 1984 1985 < 500 18,168 19,604 492,610 485,150 23.3 24.2

	500-1,000 193 195 132,830 137,100 6.3 6.8 1,000-2,500 173 157 268,565 244,550 12.7 12.2 2,500-5,000 82 71 290,960 250,260 13.8 12.5 5,000-10,000 39 36 264,945 242,455

	12.6 12.1 10,000-25,000 19 19 322,020 308,450 15.3 15.4 > 25,000 7 7 338,380 339,375 16.0 16.9 The following table depicts the even more dramatic subdivision of large tracts of cultivated land and/or grassland into more numerous smaller tracts in New Jersey between 1984 and 1995 (after Table 7 in Lathrop 2000; cultivated/grassland tracts are not defined on the basis of subdivision by highways; tracts smaller than 2.5 acres are excluded from this analysis). Cul t./grassland tract area category (acres) Number of tracts in area category Area of cult./grassland tracts in area category (acres) Proportion of total area of cult./grassland tracts in area category (%) 1984 1995

	1984 1995 1984 1985 < 500 15,727 17,445 354,985 391,795 36.4 46.3 500-1,000 106 114 74,050 76,875 7.6 9.1 1,000-2,500 56 65 92,070 97,860 9.4 11.6 2,500-5,000 28 25

	95,105 78,595 9.7 9.3 5,000-10,000 11 6 79,075 48,380 8.1 5.7 10,000-25,000 1 5 14,295 84,140 1.5 10.0 > 25,000 6 1 267,060 68,115 27.3 8.0 The estimated median patch size on nonfederal land in New Jersey is as follows (area calculated from diameter assuming circular patches; based on transect sample data from NRI 1997; these values are not predicted to be as accurate as values in Lathrop 2000, which are based on full-coverage satellite images of New Jersey):
	Cultivated cropland Non-cultivated cropland

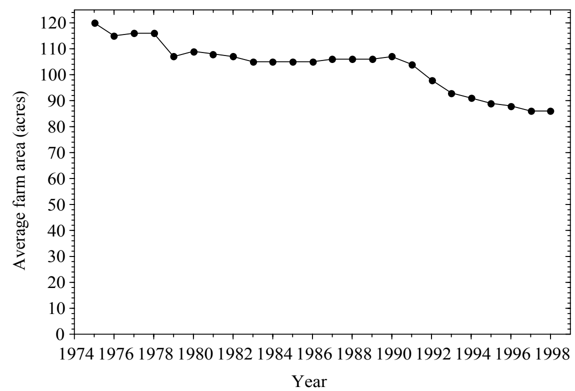
	CRP land Pasture land Forest land Other rural land Diameter (feet) 716 626 778 576 850 600 Area (acres) 9.2 7.1 10.9 6.0 13.0 6.5 The size distribution of forest patches delineated by roads in New Jersey's Barnegat Bay watershed is as follows (BBEP 2000a): Forest patch area Hectares (ha) 50-100 100-250 250-500 500-1,000 1,000-5,000 >5,000

	Acres 124-247 247-618 618-1,235 1,235-2,471 2,471-12,355 >12,355 All roads as boundaries: # Patches 159 128 42 11 3 Total area ha 11,377 20,030 15,111 7,425 3,997 acres 28,112 49,493 37,339 18,347 9,876 Only major roads (interstate, state and county level) as boundaries:

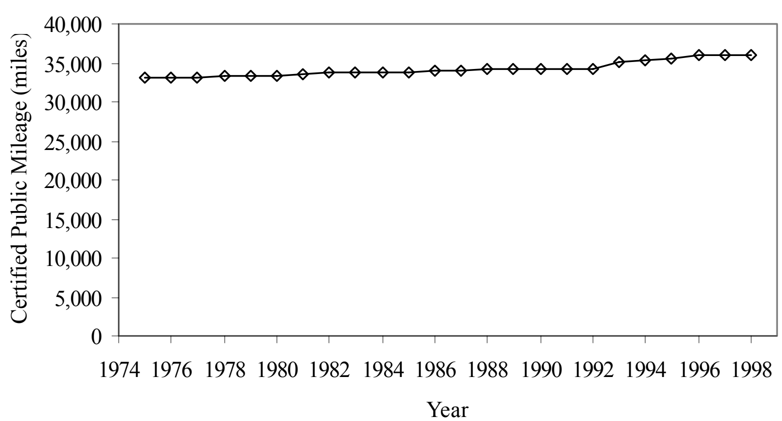
	# Patches 39 28 16 14 15 2 Total area ha 2,701 4,567 5,578 10,348 34,904 19,649 acres 6,674 11,285 13,783 25,570 86,247 48,552 Between 1972 and 1988, the number of forest patches increased both inside and in neighboring areas outside the New Jersey Pinelands National Reserve, and the average size of forest patches decreased. These trends of increasing fragmentation were less severe inside the Reserve than outside (Luque et al. 1994): Inside Reserve Outside Reserve

	1972 1988 Percent change 1972 1988 Percent change Number of forest patches 309 622 101.3 605 1293 113.7 Average forest patch size ha 333 169 -49.4 56 24 -58.0 acres 823 417 139 59

Between 1972 and 1988, the total amount of edge between forest and non-forest increased 15% inside the Pinelands Reserve and 25% in neighboring areas outside. In the same time period inside the Reserve, average patch size of mixed deciduous forests decreased 21%, and average patch size of pine forests decreased 26%. In neighboring areas outside the Reserve, average mixed deciduous forest patch size decreased 72% and pine forest patch size decreased 44% (Luque et al. 1994).
Only 1% of the land area of the New Jersey Highlands consists of forest patches larger than 5,000 acres, and 75% of the land area is in forest patches smaller than 50 acres (NJDEP 1998a).
Average size of individual farms has been declining for the past quarter-century, as shown in the following graph (includes Christmas tree farms starting in 1991; after data in NJASS 1999).



The number of miles of public roads in New Jersey has increased by almost 9% from 1975 to 1998, as depicted in the following graph (after data in NJDOT 2001).



	Quantitative impact/response assessment Birds Robbins et al. (1989) identified 26 bird species in the mid-Atlantic for which the probability of being found in forest patches increased with patch size. The following table (after Table 5 in Robbins et al. 1989) presents the patch areas at which this probability was highest. All of these species breed in New Jersey (Sauer et al. 1999). Robbins et al. (1989) suggest that the minimum forest patch size for breeding is half as large as the area at which probability of occurrence is highest. They also suggest that 3,000 ha (7,413 acres) is the minimum forest patch size expected to retain all species of forest-breeding birds. Species Forest patch area at which probability of occurrence reaches a maximum Forest patch area at which probability of occurrence is half of maximum ha acres ha acres Acadian flycatcher (Empidonax virescens) ≥ 3,000 ≥ 7,413 15.0 37.1 Great crested flycatcher (Myiarchus crinitus) 72 178 0.3 0.7 Blue-gray gnatcatcher (Polioptila caerulea) ≥ 3,000 ≥ 7,413 15.0 37.1
	Veery (Catharus fuscescens) 250

	618 20.0 49.4 Wood thrush (Hylocichla mustelina) 500 1,235 1.0 2.5 Red-eyed vireo (Vireo olivaceus) ≥ 3,000 ≥ 7,413 2.5 6.2 Northern parula (Parula americana) ≥ 3,000 ≥ 7,413 520.0 1,284.9 Black-throated blue warbler (Dendroica caerulescens) ≥ 3,000 ≥ 7,413 1,000.0 2,471.0 Cerulean warbler (Dendroica cerulea) ≥ 3,000 ≥ 7,413
	700.0 1,729.7 Black-and-white warbler (Mniotilta varia)

	≥ 3,000 ≥ 7,413 220.0 543.6 Worm-eating warbler (Helmitheros vermivorus) ≥ 3,000 ≥ 7,413 150.0 370.6 Ovenbird (Seiurus aurocapillus) 450 1,112 6.0 14.8 Northern waterthrush (Seiurus noveboracensis) ≥ 3,000 ≥ 7,413 200.0 494.2 Louisiana waterthrush (Seiurus motacilla) ≥ 3,000 ≥ 7,413 350.0 864.8
	Kentucky warbler (Oporornis formosus) 300 741 17.0 42.0

	Canada warbler (Wilsonia canadensis) ≥ 3,000 ≥ 7,413 400.0 988.4 Summer tanager (Piranga rubra) ≥ 3,000 ≥ 7,413 40.0 98.8 Scarlet tanager (Piranga olivacea) ≥ 3,000 ≥ 7,413 12.0 29.7 Rose-breasted grosbeak (Pheucticus ludovicianus) ≥ 3,000 ≥ 7,413 1.0 2.5 Red-shouldered hawk (Buteo lineatus)* ≥ 3,000 ≥ 7,413
	225.0 556.0 American crow (Corvus brachyrhynchos) 10 25 0.2 0.5

	White-breasted nuthatch (Sitta carolinensis) 300 741 3.0 7.4 Red-bellied woodpecker (Melanerpes carolinus) 85 210 0.3 0.7 Hairy woodpecker (Picoides villosus) 200 494 6.8 16.8 Pileated woodpecker (Dryocopus pileatus) ≥ 3,000 ≥ 7,413 165.0 407.7
	Tufted titmouse (Parus bicolor) 52 128 0.5 1.2 *State-Threatened species New Jersey mixed-oak forest patches of 0.2 ha (0.5 acres) or smaller consist entirely of "edge" habitat, containing a limited number of bird species (Galli et al. 1976). Galli et al. (1976; Table 4) identified minimum forest patch size for 18 New Jersey bird

	species that avoid edge habitat, as follows (based on absence of these species in censuses of smaller patches): Minimum forest patch area Species ha acres Blue jay (Cyanocitta cristata) 0.8 2.0 Brown thrasher (Toxostoma rufum) 0.8 2.0 Cardinal (Cardinalis cardinalis) 0.8 2.0 Great crested flycatcher 0.8 2.0 Red-eyed vireo 0.8 2.0
	Wood thrush 0.8 2.0 Downy woodpecker (Picoides pubescens) 1.2 3.0 Black-capped chickadee (Parus atricapillus) 2.0 4.9 Eastern wood pewee (Contopus virens) 2.0

	4.9 Hairy woodpecker 2.0 4.9 White-breasted nuthatch 2.0 4.9 Red-bellied woodpecker 3.0 7.4 Scarlet tanager 3.0 7.4 Ovenbird 4.0 9.9 Yellow-billed cuckoo (Coccyzus americanus) 4.0 9.9

Black-and-white warbler
7.5
18.5

Black-billed cuckoo (Coccyzus erythropthalmus)
7.5
18.5

Red-shouldered hawk
10.0
24.7

In a survey of New Jersey hawks and owls, Bosakowski and Smith (1997) found that no forest patch smaller than 1,000 ha (2,471 acres) had more than 4 different species of these birds, whereas forests from 1,000 – 8,000 ha (19,768 acres) had up to 8 different species. Another survey found that Cooper's hawks (Accipiter cooperii; a State-Threatened species) selected nesting sites with an average forest cover of 87% (Bosakowski et al. 1993).

In otherwise-intact New Jersey forest patches greater than 1,000 ha (2,471 acres), the abundance of forest-nesting bird species is significantly reduced (relative to their abundance in forest interior habitat) along paved roads and powerline rights-of-way averaging 16 and 23 m (52 and 75 feet) in width. Relative abundance is not reduced along unpaved roads that average 8 m (27 feet) wide (Rich et al. 1994).

Parasitic brown-headed cowbirds and birds that raid nests of other forest bird species (American crows, fish crows [Corvus ossifragus], blue jays, and common grackles [Quiscalus quiscula]) are attracted to forest-dividing paths that are as narrow as 8 m (27 feet; Rich et al. 1994).

Amphibians

In a study in southern Connecticut, wood frogs (Rana sylvatica) and spotted salamanders (Ambystoma maculatum) were not found in habitat where forest was fragmented to less than 30% of land cover, and red-spotted newts (Notophthalmus viridescens viridescens) were absent where forest was less than 50% of land cover (Gibbs 1998).

In central Maine, abundance of wood frogs and spotted salamanders in disturbed habitat (2 – 11 years since clearcutting) was significantly lower than in closed-canopy forest (70 – 90 years old), and abundance of both species increased with increasing distance into the forest interior away from the forest edge (DeMaynadier and Hunter 1999). These results are also likely to apply to these and similar species in New Jersey.

Freshwater animals and plants

Eight of the twelve native species of freshwater mussel found in New Jersey are either Federally/State-Endangered, listed as species of special concern, or are under consideration for listing (NJDFGW 2000).

	Dose-response information is unavailable for New Jersey, but Blalock and Sickel (1996) found an 86% reduction in the number of native mussel species between 1911 and 1994 in a section of Cumberland River, Kentucky, which they attributed mainly to impoundment of the river by Barkley Dam. Dune vegetation communities Dune habitats along the New Jersey coastline from 1 – 5 m (3.3 – 16.4 feet) wide are too small and short-lived (seasonal) to support vegetation communities beyond the initial colonization stage. Dunes from 5 – 30 m (16.4 – 98.4 feet) wide last for years to decades, and dunes wider than 30 m (98.4 feet) last for decades, allowing increasing potential for species diversity with increasing size (Nordstrom et al. 2000). Road effects In one study, diverse ecological effects of a Massachusetts highway extended, on average, 300 m (984 feet) into surrounding habitat on either side of the highway (Forman and Deblinger 2000); a similar zone is also likely to be found in New Jersey.	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced	The impacts described above are consistent with habitat fragmentation resulting in serious damage to ecosystems, with reductions in biodiversity, so an assessment of 3 would be inadequate. Ecosystems will not become lifeless and the process may be partially reversible over long time periods, so an assessment of 5 would be excessive.	4

Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Fragmentation is an ongoing, continuous process, and is increasing (Lathrop 2000). Recent regulatory efforts to curtail habitat loss may result in at least a stabilization of fragmentation rates.	5
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	As quantified above, much more than 50% of the State is exposed to habitat fragmentation.	5
	Total	100
Assessment of uncertainties in this assessment (H,M,L) and brief description	L: Few uncertainties exist concerning the statewide extent of habitat fragmentation. It is less clear what the quantitative response of populations and ecological communities in New Jersey will be to fragmentation, but responses are likely to be qualitatively similar to those described in this report.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data	L: Although few data are available on the effects of fragmentation on organisms and ecosystems in New Jersey specifically, a large body of scientific research in other systems and regions supports the seriousness of the impacts described in this template. The qualitative description given here is unlikely to be altered significantly by additional data. Recent publication of data sets with high spatial resolution (BGIA 2000; Lathrop 2000; Lathrop et al. 2000) allows quantitative analysis of habitat fragmentation at the	

needs)	State and County levels, especially rates of change in habitat patch size and projections of future trends in habitat fragmentation due to development. There needs to be more research that focuses directly on the effects of habitat fragmentation (and not just habitat loss) on New Jersey plants and animals other than birds and amphibians. More research should be undertaken in the New Jersey context to address the suggestion that habitat fragmentation may release crop pests from natural predators.
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	0: The underlying risks of habitat fragmentation will remain, although prudent management may reduce its extent and effects.
Potential for catastrophic impacts (H,M,L) and brief description	L: Effects of habitat fragmentation are likely to be gradual and incremental, rather than sudden.
Link to other Work Groups (e.g., socioeconomic impacts)	By reducing biodiversity, habitat fragmentation may impair the wilderness experience of people who seek out wildlife and natural habitats for recreational purposes. By disrupting ecosystem functions, fragmentation may reduce the ability of ecosystems to provide services vital for human health, like purifying air and water. By reducing the size of forest fragments below the space requirements of certain bird species, habitat fragmentation could conceivably result in the release of agriculturally important pest species from natural control by these bird species. By potentially reducing natural predators of agricultural pests, habitat fragmentation may lead to an increased use of pesticides, and thus an increase in the harmful side-effects of pesticides.
Extent to which threat is currently regulated or otherwise managed	Habitat fragmentation is identified as a significant risk requiring management attention in major land use and conservation plans applicable to the State of New Jersey, including the Interim New Jersey State Development and Redevelopment Plan (NJOSP 1999b), and the Comprehensive Conservation and Management Plans for the Barnegat Bay (BBEP 2000b), Delaware (DEP 1996) and New York-New Jersey Harbor Estuary Programs (HEP 1996). As of 1998, New Jersey had 920,000 acres of permanently protected open space (all ownerships; NJDEP 1998b). The Garden State Preservation Trust Act of 1999 establishes a stable funding source to preserve 1,000,000 acres of additional open space and farmland over the next ten years. The funding to meet this ambitious goal was approved by a 1998 public vote amending the State constitution (Green Acres 2000). More than 390,000 acres of open space have been preserved through the New Jersey Green Acres Program since its inception in 1961. This land is managed by divisions of the NJ Department of Environmental Protection (Green Acres 2000). Development of inland wetlands is restricted by the Freshwater Wetlands Protection Act of 1987, which requires, as a condition of granting permits to develop freshwater wetlands, that measures be taken to mitigate adverse environmental impacts, including in some cases the creation of new wetlands to replace any lost to development (N.J.S.A. 13:9B).

The New Jersey Farmland Preservation Program, administered by the State Agriculture Development Committee, has safeguarded 62,000 acres of agricultural land from development since its inception in 1981 (NJDA 2000).

Development – and, therefore, fragmentation – is regulated in the 1.1 million acre New Jersey Pinelands National Reserve by the Pinelands Commission. 927,000 acres of the Pinelands National Reserve constitute the Pinelands Area as defined by the New Jersey State Pinelands Protection Act of 1979. Development is most highly restricted in the 295,000 acres of the Pinelands Area classified as the Preservation Area District, and is also limited in the Agricultural Production Areas (66,200 acres) and Forest Areas (400,000 acres; NJPC 2000a). The Preservation Area District is likely to experience the least additional fragmentation of the Reserve's regions. The Agricultural and Forest Areas are likely to experience less additional fragmentation than regions of the Reserve in which development is less restricted. From 1990 to 1998, the human population growth rate was proportionately higher in the Pinelands than in all other areas of New Jersey, but 97% of approved development applications in 1999 were in Regional Growth Areas, Rural Development Areas, and towns and villages, and not in the Preservation, Agricultural or Forest Areas (NJPC 2000b).

Walker and Solecki (1999) conclude that the Pinelands Reserve has been effective at reducing development. They reported a 7.9% increase in development in the core preservation area of the Pinelands Reserve from 1975 (before the Protection Act went into effect) to 1986, much less than the 40.5% increase in development in peripheral growth areas in the same time period.

At the Federal level, the U.S. National Park Service is involved in the management of three parks entirely or partially within New Jersey. These areas experience heavy human activity, but additional fragmentation within them is likely to be minimal:

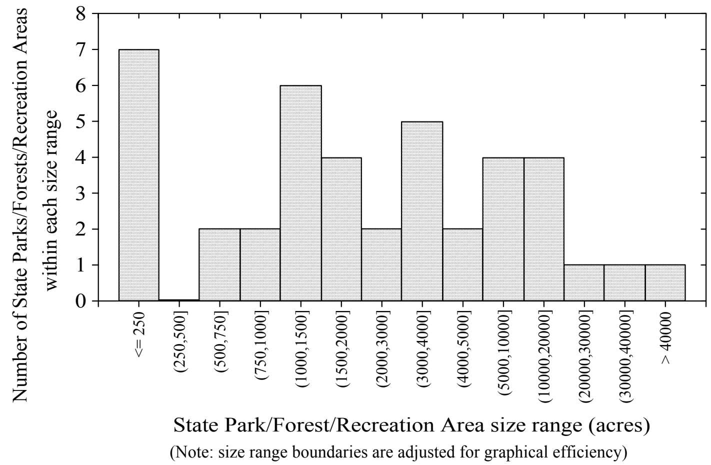
The 67,205 acre Delaware Water Gap National Recreation Area, of which 55,162 acres are Federally owned and 12,043 acres are Non-Federal. This Recreation Area is shared between Northwestern New Jersey in the counties of Warren and Sussex, and in Northeastern Pennsylvania in the counties of Northampton, Monroe and Pike (DWGNRA 2000).

The 1,700 acre Morristown National Historical Park, which is divided into four non-contiguous sections (NPS 2000).

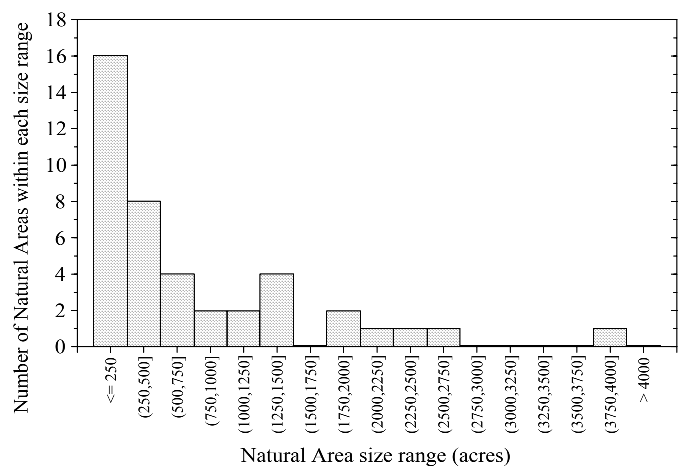
The 73.4 miles of the Appalachian Trail that lies within New Jersey (ATC 2000).

The Division of Parks and Forestry, NJ Department of Environmental Protection, administers 41 State Parks, State Forest and Recreation Areas, totaling 300,645 acres. Several of these lie within the Pinelands National Reserve. These areas experience varying levels of human activity, and the proportion of continuous habitat within each varies, but additional fragmentation within these areas is likely to be minimal. The average area of State Parks, State Forests and Recreation areas is 7,333 acres, and the median area is 1,910 acres.

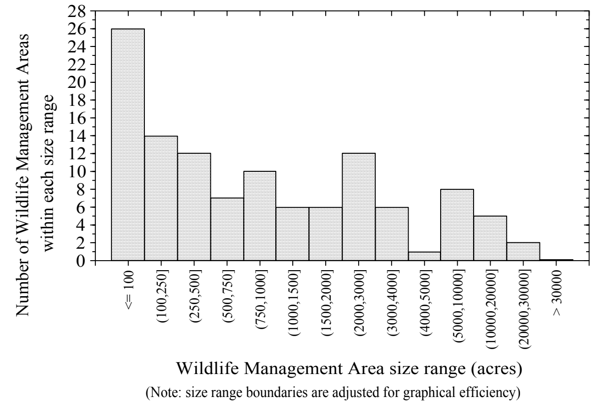
The size distribution of these Parks, Forests and Recreation areas is shown in the following graph (DPF 2000a):



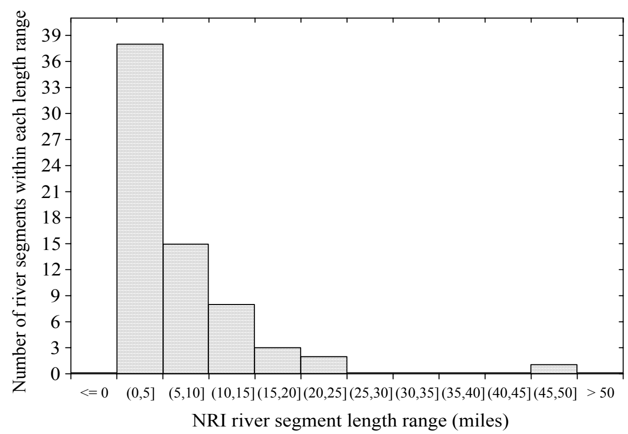
The Natural Areas System, administered by the NJ Division of Parks and Forestry, protects 42 sites totaling 31,284 acres. Many of the Natural Areas lie within State Parks and State Forests. This System is intended to protect endangered and threatened plants and animals, significant natural ecosystems and exemplary wildlife habitats. It is, therefore, unlikely that Natural Areas will experience further fragmentation. The average area of Natural Area System sites is 745 acres, and the median area is 404 acres. The size distribution of these sites is shown in the following graph (after data in DPF 2000b):

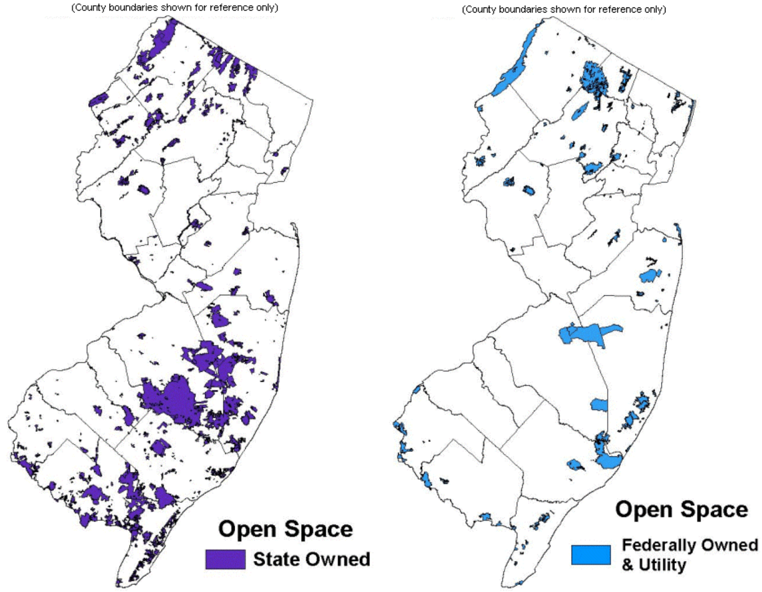


As of May 2000, the Bureau of Land Management, New Jersey Division of Fish and Wildlife, managed 115 Wildlife Management Areas totaling 265,397 acres (BLM 2000a). In Wildlife Management Areas, fish and wildlife habitat is protected and enhanced, while providing a variety of compatible recreational and educational opportunities (BLM 2000b). Consequently, additional fragmentation of these areas is likely to be minimal. The average area of Wildlife Management Areas is 2,308 acres, and the median area is 714 acres. The size distribution of these sites is shown in the following graph (after data in BLM 2000a):



67 river segments in New Jersey, totaling 490 miles in length, are classified in the National Rivers Inventory (NRI), and by presidential directive all federal agencies must avoid or mitigate adverse effects on these river segments (NRI 2000). Although all development along these segments is not prohibited, they are at reduced risk of further fragmentation (i.e., construction that would interrupt their flow). The mean length of New Jersey river segments in the National Rivers Inventory is 7.3 miles, and the median length is 5 miles. The length distribution of these segments is shown in the following graph (after data in NRI 2000):



	The following maps depict areas of open space protected under New Jersey State and Federal ownership (NJDEP 1999). 
Barriers to restoration	Re-establishing connectivity among fragmented habitats would require acquisition and remediation of developed land. Due to human population pressures in New Jersey, returning currently developed land to its former state is not practical on a large scale. The major management response to habitat fragmentation should be preventing further fragmentation.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	M
Small business industry	L
Transportation	H
Residential	H
Agriculture	M
Recreation	L
Resource extraction	L
Government	L

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Natural sources/processes	NA
Orphan contaminated sites	NA
Diffuse Sources	
Sediment sinks	NA
Soil sinks	NA
Non-local air sources incl. deposition	NA
Biota sinks	NA

Summary Statement:

Habitat fragmentation is the subdivision of previously continuous habitat by development, transportation corridors and other human activities. Fragmentation results in a number of ecosystem changes at many different spatial and temporal scales. Remaining habitat fragments support fewer species of plants and animals, and lower abundance of individual species. Impacts of fragmentation are particularly severe on species requiring large habitat patches, such as forest-breeding birds, and species that must travel between habitats, such as amphibians. However, a wide range of other organisms are also likely to be adversely affected by habitat fragmentation. Virtually the entire area of New Jersey is at risk of habitat fragmentation. In recognition of the undesirability of habitat fragmentation and loss, legislators have placed large areas of the State under protection from unregulated development. The high risk score given by this template to habitat fragmentation is consistent with the large spatial and temporal scales at which it operates, and the severity of its impacts on ecosystems.

Statewide Analysis of Threat Threat =

Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	4	5	5	100
Marine Waters	4	5	5	100
Wetlands	4	5	5	100
Forests	4	5	5	100
Grasslands	4	5	5	100
			Total Score	500
			Average Score (Total ÷ 5)	100

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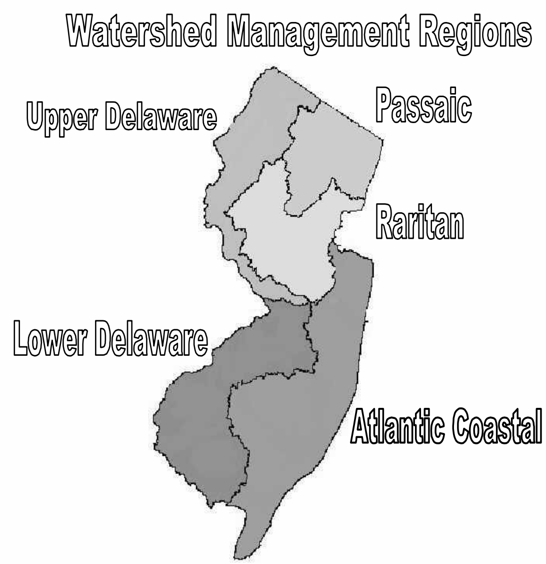
Risk by Watershed Management Region

THREAT =	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	H	NA	H	H	H
Passaic	H	H	H	H	H
Raritan	H	H	H	H	H
Atlantic	H	H	H	H	H
Lower Delaware	H	H	H	H	H
Region/Watershed (secondary)					
Urban	NA	NA	NA	NA	NA
Suburban	H	NA	H	H	H
Rural	H	NA	H	H	H

H=high, M=medium, L=low, NA = not applicable



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.**New Jersey Comparative Risk Project**
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Habitat Loss**
Description of stressor	The change in land use and/or cover from one type to another. The specific stressor considered in this assessment is the conversion of undeveloped (including agricultural) habitats, primarily to urban and suburban uses, resulting in a loss of the total area of undeveloped land in New Jersey. In addition, habitat loss includes the conversion of natural to agricultural lands, the conversion of dunes to seawalls, and the modification of wetland habitats by dams and channelization. Habitat loss frequently results in the fragmentation of formerly continuous habitats into smaller patches. Important impacts of fragmentation are described in the separate *Habitat Fragmentation* risk assessment. Although, to avoid redundancy, these fragmentation-specific impacts are not repeated here, they must be considered in addition to the more general impacts of habitat loss *per se* that are described in this assessment.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	Biological integrity Habitat loss results in changes in the assemblages of species found in remaining undeveloped habitat in both space and time (see, e.g. Boulinier et al. 1998). Habitat disturbance caused by habitat loss results in increased susceptibility of ecological communities to invasion by exotic (non-native) species (see, e.g., Crawley 1987; Dobson et al. in press). Native species abundance declines with increasing urbanization (see, e.g., Blair 1996). Loss or degradation of critical habitat may lead to the extirpation of "keystone" species that have disproportionately large ecological effects for their abundance. Their disappearance can cause large changes in community structure (Chapin et al. 1997). Biodiversity Habitat loss and associated impacts are the single greatest threat to biodiversity in the United States (Noss and Peters 1995; Noss et al. 1995; Wilcove et al. 2000). Nationally, habitat loss and degradation contribute to the endangerment of 85% of imperiled species, with agriculture, urban and suburban development, and water development being the types of habitat degradation that imperil the most species (Wilcove et al. 2000). Reduction in the area of habitats suitable for different species of animals and plants reduces biodiversity, because species that are unable to adapt to changed habitats are wiped out of the altered portion of their former range (Dobson 1996). Biodiversity declines in a region as the amount of urban development increases (see, e.g., Lehtinen et al. 1999). Increased disturbance by human activity can cause reproductive failure in sensitive species (see, e.g., Burger et al. 1995).

	Habitat/ecosystem health Habitat loss is frequently accompanied by increased exposure of ecosystems to pollution, disturbance from outdoor recreation, and disruption of fire ecology, all of which seriously damage ecosystem health (Wilcove et al. 2000). Habitat conversion by human activity increases the exposure of ecosystems to contaminants that are concentrated up the food chain, poisoning top predators (e.g., chlordane-poisoning of State-Threatened Cooper's Hawks feeding on songbirds in suburban NJ; Stansley and Roscoe 1999). Both urban and agricultural areas are sources of pesticides that threaten non-target species (e.g., Hoffman et al. 2000). Land development threatens the health of aquatic ecosystems by directly converting wetland habitat, as well as by increasing erosion, resulting in siltation of waterways. These and related impacts of habitat loss on aquatic ecosystems are largely responsible for a higher proportion of freshwater species than of terrestrial species being imperiled nationwide (Master et al. 1998). Ecosystem function Habitat loss damages vital ecosystem functions, reducing the ability of ecosystems to purify air and water, reducing the productivity of natural and agricultural lands, changing the frequency of disturbances such as fire, and even changing local and global climate (Baskin 1997).
Key impacts selected (critical ecological effects)	Biological integrity, Biodiversity and Habitat/ecosystem health: impacts as listed above. Insufficient New Jersey-specific information is available to evaluate Ecosystem function impacts beyond the general statement of impacts given above.
Exposure Assessment	
Exposure routes and pathways considered	Habitat loss resulting from land conversion from forest/rural/agricultural to urban/suburban and forest to agricultural. Conversion and degradation of wetlands.
Population(s)/ecosystem(s) exposed statewide	All terrestrial and aquatic animal and plant populations and ecosystems statewide, especially those that are found on undeveloped, unprotected land. Particularly high exposure of unprotected forest and wetland ecosystems statewide. Erosion effects (e.g., siltation) expose freshwater and marine ecosystems to impacts of habitat loss. Agricultural land.
Quantification of exposure levels statewide	**Spatial:** As of 1995, the areas of different habitat types in New Jersey were as presented in the following table. Differences in values reported by the two sources (BGIA 2000 and Lathrop 2000) are due to differences in their methodologies and land classification schemes.

BGIA (2000) Land Use/Land Cover Level 1 Category	Area (acres)	Lathrop (2000) Land Cover Level 1 Category	Area (acres)
Urban	1,342,525	Developed	1,427,310
Agriculture	659,017	Cult/grass	883,590
Forest	1,602,577	Upland Forest	1,421,060
Barren Land	57,971	Bare Land	45,530
Wetlands	1,033,470	Coastal wetland	201,570
		Inland wetland	737,010
Water	788,405	Water	514,960
		Unconsolidated shore	45,880

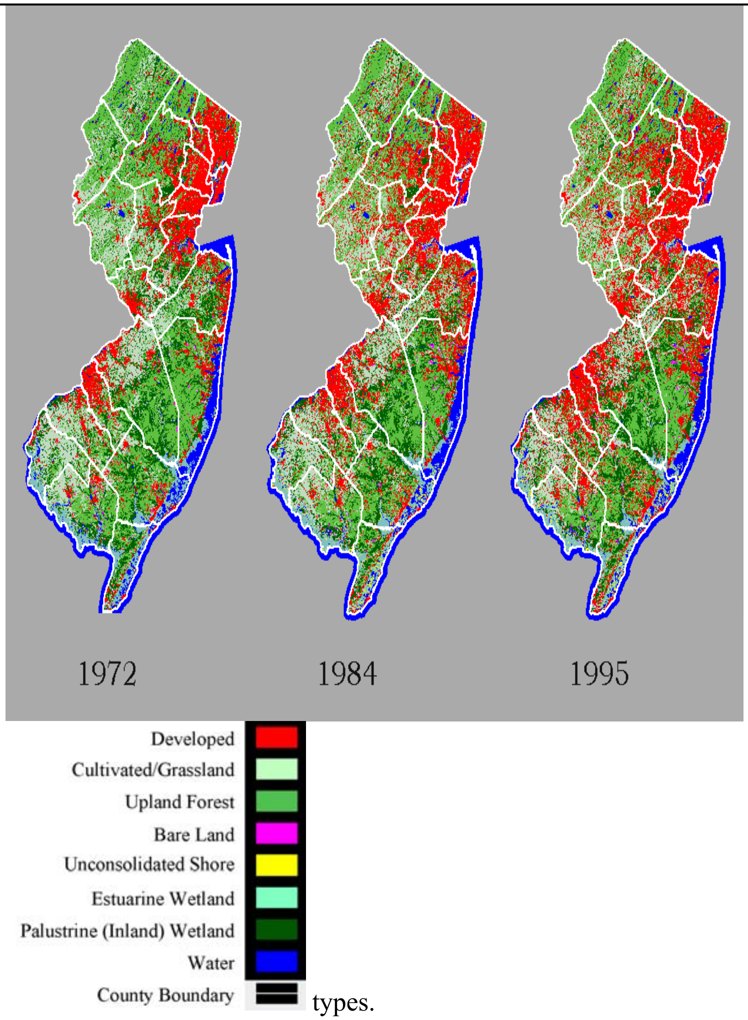
Due to methodological and land-classification differences, USDAFS (2000) reports a greater area of total forested land in New Jersey than either BGIA (2000) or Lathrop (2000; see previous table): 1,991,000 acres. USDAFS (2000) is of particular value in the present context for classifying ownership of forested land, as presented in the following table (1997 values). Note that the great majority of all forested land in New Jersey is privately owned, and thus more difficult to protect than if it were owned by government.

	Federal	**State of NJ**	**County and municipality**	**Total public**	**Private**
Area (× 1000 acres)	96	382	127	605	1,386
Percentage of total forested land	4.8	19.2	6.4	30.4	69.6

Regions of particular importance because they still contain large tracts of critical wildlife habitat but are vulnerable to loss include the New Jersey Pinelands (1.1 million acres; NJPC 2000a) and the New Jersey Highlands. The Highlands are 640, 478 acres, of which 334,871 acres are classified under the State Planning Area system as Environmentally Sensitive, and 158,104 acres are classified as Rural and Rural/Environmentally Sensitive (NJOSP 1999a).

Temporal:

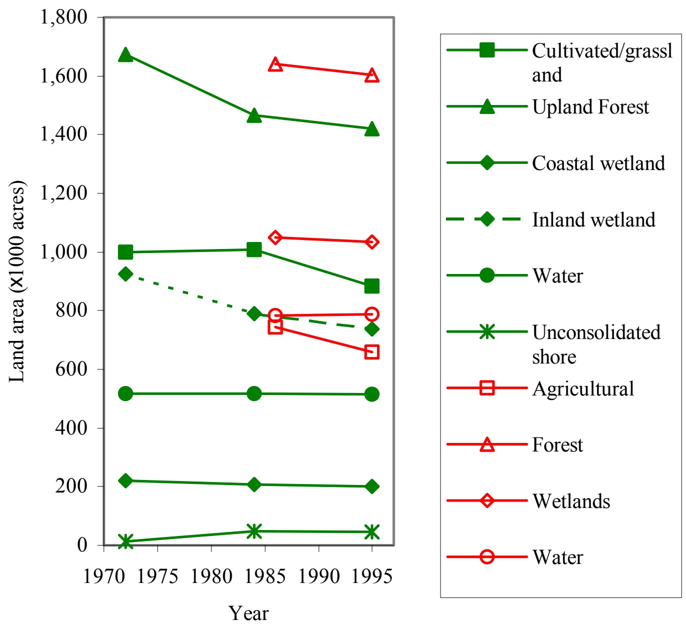
The following three maps depict the change in land cover in New Jersey from 1972 to 1995 (maps generated with Interactive Mapping utility, Lathrop et al. 2000). Note the increase in developed land (red) and decline in undeveloped habitat



types.

The following graph presents the decline from 1972 to 1995 in the areas of specific undeveloped habitat types. Differences between the two sources (BGIA 2000 and Lathrop 2000) are due to differences in their methodologies and land classification schemes. Both sources report qualitatively similar trends (open, red symbols = BGIA 2000; solid, green symbols = Lathrop 2000).

Most federally owned land in New Jersey is under some form of protection from habitat loss, but the vast majority of land in New Jersey is not federally owned. Total nonfederal land in New Jersey, excluding water areas, is 4,537,100 acres. This is 87% of the total area of New Jersey, and 97% of the total non-water area of New Jersey. Of this amount, 1,848,900 acres (41%) is developed land (1997 values from NRI 1997). Undeveloped nonfederal land is 2,688,200 acres. This is 57% of the total non-water area of New Jersey, and 59% of the total nonfederal land area (1997 values; NRI 1997).



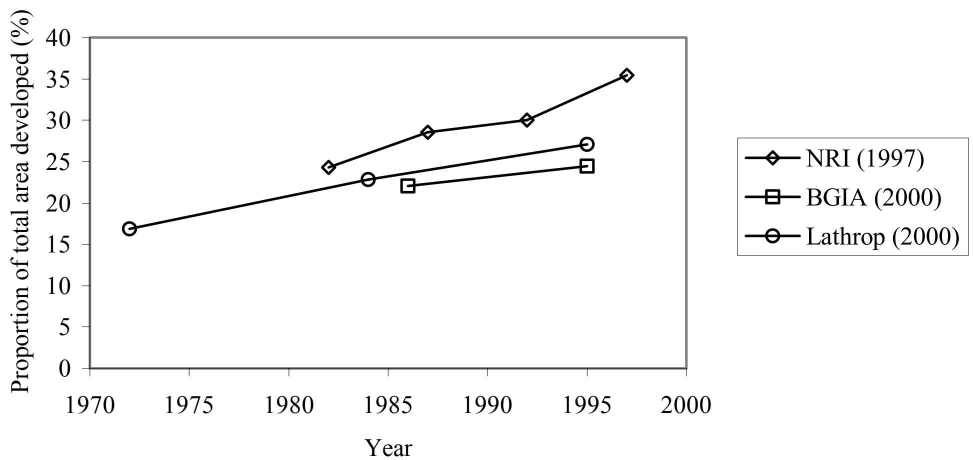
Specific population(s) at increased risk	Habitat loss is expected to have negative effects on most species in a wide range of different groups of plants and animals in New Jersey. This prediction arises from the fact that habitat loss and degradation is the leading cause of endangerment for all groups of organisms in the mainland U.S., from beetles to mammals to plants, ranking ahead of exotic (non-native) species, pollution, overexploitation and disease (Wilcove et al. 2000). The following is a small selection of habitat loss impacts on organisms that have been documented within the State of New Jersey, but this list should not be considered exhaustive (for additional examples, see the *Habitat fragmentation* assessment). **Birds** In the mid-Atlantic region (which includes New Jersey), bird species diversity decreases as the proportion of urban land increases (Cam et al. 2000). Barred owls (*Strix varia*), red-shouldered hawks (*Buteo lineatus*; both State-Threatened in New Jersey), and State-Endangered northern goshawks (*Accipiter gentilis*) require forested habitat and avoid suburban areas (Laidig and Dobkin 1995; Bosakowski and Smith 1997). **Amphibians** Water in wetlands disturbed by development and agriculture has different quality, including pH (acidity/alkalinity) and nitrogen content, than does water in less disturbed wetlands. This affects suitability of habitats for amphibians. For example, adults of frog species that are not normally found in intact habitats of the New Jersey Pinelands are able to enter the Pinelands at the border of land disturbed by human activities (Bunnell and Zampella 1999). Bullfrogs (*Rana catesbiana*) are not native to the Pinelands but are found in Pinelands habitat next to human-altered land. Native Pine Barrens treefrogs (*Hyla andersonii*), a State-Endangered species, are not found in areas occupied by bullfrogs, indicating that bullfrogs may prey on or compete with this species, thus altering native frog diversity (Zampella and Bunnell 2000). **Insects** The Mitchell's satyr butterfly (*Neonympha mitchellii mitchellii*) is federally listed as Endangered under the Endangered Species Act (ESA). Although it is still listed by the New Jersey Division of Fish and Wildlife as State-Endangered, this species is considered to be extirpated from New Jersey, and habitat loss (Shuey 1997) combined with over-collecting (Jeanette Bowers-Altman, pers. comm.) are the probable causes of its decline. The American burying beetle (*Nicrophorus americanus*) is federally listed as Endangered under the Endangered Species Act (ESA). Although it is still listed by the New Jersey Division of Fish and Wildlife as State-Endangered, this species has not been found in New Jersey since the 1920s, and habitat loss has been implicated in its decline (USFWS 1991a).

	Plants Plant diversity is lower in New Jersey Pinelands Atlantic white cedar swamps as the amount of residential and agricultural development increases (Laidig and Zampella 1999). In plant communities associated with streams in the New Jersey Pinelands, exotic species have replaced native Pine Barrens species in sites with heavy residential or agricultural development (Zampella and Laidig 1997). Within a New Jersey watershed, fewer populations of the federally and State-Endangered swamp pink (*Helonias bullata*) are found as the proportion of urban land increases (Windham and Breden 2000). Aquatic organisms The diversity and abundance of aquatic species in the Newark Bay estuary, New Jersey, has declined since the late 1800s as a result of urbanization and industrialization, which have destroyed wildlife habitat directly as well as impairing water and sediment quality (Crawford et al. 1994). Freshwater mussels have also declined in NJ since the late 1800s due to water quality degradation related to habitat modification by channelization and dams (Jeanette Bowers-Altman, pers. comm.).
Quantification of exposure levels to population(s) at increased risk	See above, under "Quantification of exposure levels statewide", for areas of habitat types in which particular populations are exposed (e.g., birds are exposed primarily in forested land; aquatic organisms are exposed primarily in wetlands and bodies of water; agricultural habitats are exposed primarily in cultivated land).
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	Quantitative dose assessment Historical trends The following table presents the change in area of different habitat types in New Jersey from the mid-1980s to mid-1990s. Differences in the magnitude of change between the two sources (BGIA 2000 and Lathrop 2000) are due to differences in their methodologies and land classification schemes. Both sources reveal an increase in land developed for urban uses with a corresponding decrease in critical wildlife habitat (forest, wetlands and grasslands) and agricultural lands.

BGIA (2000) 1986 – 1995		**Lathrop (2000) 1984 – 1995**	
Land Use/Land Cover Level 1 Category	Area change (gain +; loss -)	Land Use/Land Cover Level 1 Category	Area change (gain +; loss -)
Urban	+133,973	Developed	+222,390
Agriculture	-85,365	Cult/grass	-123,390

Forest	-38,702	Upland Forest	-44,620
Barren Land	+748	Bare Land	+7,080
		Coastal wetland	-6,710
Wetlands	-15,799	Inland wetland	-51,860
Water	+5,145	Water	-1,610
		Unconsolidated shore	-1,280

The following graph presents the increasing percentage of New Jersey's total area that has been covered by developed, non-agricultural land during the past two decades, according to three different analyses: NRI (1997), BGIA (2000) and Lathrop (2000). Because NRI (1997) extrapolates areas from a number of point samples whereas BGIA (2000) and Lathrop (2000) measure areas directly from aerial and satellite images, respectively, the latter two sources should be considered to be more accurate than NRI (1997).



If data sampling reported in NRI (1997) has similar biases across years, this study is still informative about the relative change in rates of development in New Jersey. According to NRI (1997), the speed at which undeveloped land is being converted to developed land in New Jersey appears to be increasing. From 1982 to 1992, the average rate of conversion of nonfederal land from undeveloped to developed uses was 29,860 acres/year, but from 1992 to 1997, the average rate of conversion was 56,640 acres/year (NRI 1997).
According to NRI (1997), the changing area of different types of rural (undeveloped) land in New Jersey, from 1982 to 1997, was as follows:

Area (× 1000 acres)

Year	Cropland	CRP land	Pastureland	Forest land	Other rural land	Total rural land
1982	809.5	0.0	239.0	1,866.7	389.9	3,305.1
1987	688.0	0.0	179.2	1,814.0	391.4	3,072.6
1992	649.6	0.5	158.9	1,784.7	387.6	2,981.3
1997	574.0	0.5	108.5	1,624.7	380.5	2,688.2

New Jersey has lost about 40% of its wetlands in the past 200 years. From an estimated 1,500,000 acres in the 1780s, representing 30% of the State's total area, wetlands were reduced to 915,960 acres (18% of total area) by the 1980s (Table 1 in Dahl 1990).

In the Barnegat Bay watershed, development has increased from 18% of total land cover in 1972 to 28% in 1995. This has resulted in the loss, over this time period, of 13,700 ha (33,852 acres), or 20% of the Barnegat Bay upland forest, and the loss of 1,875 ha (4,633 acres), or 6% of the wetland forest (Lathrop et al. 1999).

Riparian corridors are ecologically critical zones on either side of rivers, in which natural vegetation maintains water quality and provides important dispersal routes for animals. In the Barnegat Bay watershed, 20% of the riparian corridor area (defined as a 90 m-wide zone extending from each bank of a river) is in human-altered land uses (Lathrop et al. 1999).

Only 29% of Barnegat Bay's shoreline buffer zone remains in undeveloped cover (Lathrop et al. 1999).

More than 28% of Barnegat Bay's salt marshes have been converted to developed uses since the 1880s (Lathrop et al. 1999).

New Jersey has lost about 35% of its Pine Barrens (Noss and Peters 1995).

In the lower 10 km (6 miles) of the Cape May peninsula, 40% of the habitat needed by migratory and local wildlife has been lost to development in the past 20 years (NJDEP 1998a).

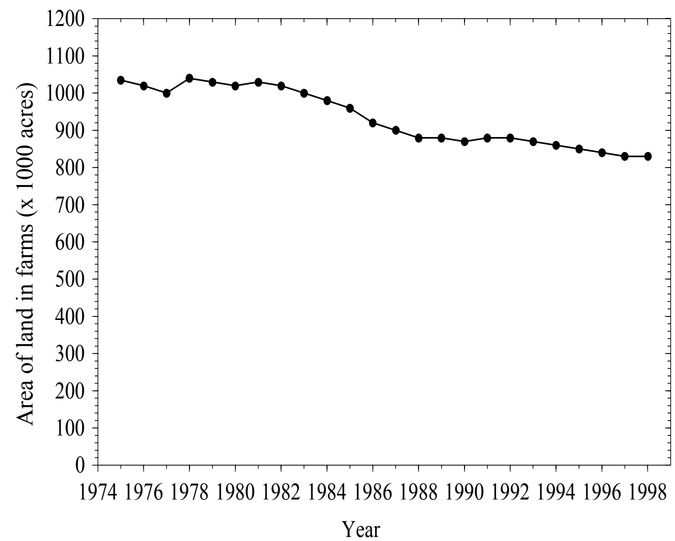
Forest losses in the Highlands region are predicted to be 20-60% over the next 25 years (NJDEP 1998b)

The following table ranks the 21 New Jersey counties by proportional rate of increase in developed land from 1984 to 1995 (relative to the area of developed land in 1984; last column; data from Lathrop et al. 2000).

		Developed land area increase, 1984 – 1995		
County	Developed land area 1984 (acres)	Acres	As proportion of total county area (%)	As proportion of 1984 value (%)
Salem	18,601	9,344	4.2	50.2
Cumberland	30,238	12,668	3.9	41.9
Atlantic	45,516	16,163	4.1	35.5
Burlington	71,645	25,133	4.8	35.1
Gloucester	51,087	17,049	7.9	33.4

Ocean	78,408	22,699	4.7	28.9
Warren	27,202	7,498	3.2	27.6
Sussex	35,637	9,322	2.7	26.2
Hunterdon	48,548	12,413	4.4	25.6
Cape May	25,125	6,243	3.4	24.8
Somerset	63,488	14,428	7.4	22.7
Monmouth	111,499	20,677	6.7	18.5
Mercer	50,801	9,408	6.4	18.5
Camden	64,253	10,259	7.1	16.0
Morris	98,379	12,976	4.2	13.2
Middlesex	93,669	9,277	4.5	9.9
Passaic	43,768	2,527	0.0	5.8
Bergen	107,458	2,414	1.5	2.2
Essex	62,065	975	1.2	1.6
Union	54,662	646	1.0	1.2
Hudson	22,851	200	0.5	0.9

Numbers of acres of New Jersey land in active farming decreased by 50% between 1950 and 1995 (NJDEP 1998b). The decreasing total amount of farmland in New Jersey since 1975 is shown in the following graph (after data in NASS 1999; Christmas tree farms were added to the total starting in 1991):



Projected trends

Noss and Peters (1995) estimated that if the rate of land development in New Jersey remained at the 1982-1992 level, all remaining undeveloped land in the state would be developed within 60 years.

In a more recent study, Hasse (2000) predicted that if land development in New Jersey remained at the 1984-1995 avera ge rate of 20,217 acres/year (value from Lathrop 2000), all remaining undeveloped land in the state would be developed within 84 years. If the state were to achieve its goal of preserving one million additional acres of undeveloped land, the remaining undeveloped land would be built out in 34 years (Hasse 2000). It may become increasingly difficult to offset the stress on remaining undeveloped land (for instance, by purchasing undeveloped land for preservation) as the amount of land available for development decreases and, therefore, as its value increases (Hasse 2000).

The supplementary environmental assessment carried out for New Jersey's State Development and Redevelopment Plan of 1992 predicted that if then-current growth trends continued over the period 1990-2010, development would take 292,079 acres of land, 36,482 acres of which would be "frail environmental lands" (forests, sensitive watersheds and steep slopes) and 108,000 acres of which would be agricultural lands. The assessment predicted that if growth were managed as in the Amended Interim Plan, development would take 117,607 acres of land, 6,139 acres of which would be frail environmental lands and 66,000 acres of which would be agricultural lands (CUPR 1992).

Quantitative impact/response assessment

Animals

Sixteen animal species that are federally listed under the Endangered Species Act as either Endangered (11) or Threatened (5) are officially listed as occurring in New Jersey (TESS 2000).

Of these, 3 Endangered species are whales that may enter New Jersey waters but that are not directly threatened by habitat loss in New Jersey. Another 3 Endangered and 1 Threatened species are sea turtles that are rarely found in New Jersey waters and do not breed on New Jersey beaches (NMFS/USFWS 1991, 1992a, b, 1993), so are not threatened by habitat loss in New Jersey.

The eastern puma (*Felis concolor cougar*) remains listed for New Jersey, but is no longer found in the State. Causes for the severe reduction of this subspecies' range include habitat destruction (USFWS 1991b).

The northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*) remains listed for New Jersey, but was extirpated from its former range in this State, primarily because of destruction and disturbance of its beach habitat (USFWS 1994a). Experimental reintroductions are occurring in New Jersey.

This leaves the following listed species not yet wiped out from New Jersey habitats; for all but one of these species, habitat loss is directly implicated in their imperilment (E=Endangered; T=Threatened):

Species	Status	Role of habitat loss in decline?
Bald eagle (*Haliaeetus leucocephalus*)	T	Yes (USFWS 1994b)
Bog turtle (northern) (*Clemmys muhlenbergii*)	T	Yes (USFWS 1997a)
Dwarf wedgemussel (*Alasmidonta heterodon*)	E	Yes (dams; USFWS 1990a)
Indiana bat (*Myotis sodalis*)	E	Possible (reduction in summer roost trees; USFWS 2000)*
Piping plover (*Charadrius melodus*)	T	Yes (USFWS 1996a)
Roseate tern (NE U.S. nesting pop.; *Sterna dougallii dougallii*)	E	No (USFWS 1992)*
Shortnose sturgeon (*Acipenser brevirostrum*)	E	Yes (dams; CRCO 2000)

*Human disturbance has played a major role in decline.

Four seabird species (common terns [*Sterna hirundo*], State-Endangered least terns [*S. albifrons*], State-Endangered black skimmers [*Rynchops niger*] and herring gulls [*Larus argentatus*]) avoid municipal and private beachfront in New Jersey for nesting, and strongly select protected federal land (69% of these birds nest on federal beaches representing just 13% of the total beachfront; Erwin 1980). Extensive human disturbance of New Jersey beachfront appears to have altered the normal nesting behaviors of these waterbirds and increased competition with other species (Erwin 1980).

State-Threatened Cooper's hawks (*Accipiter cooperii*) avoid suburban development, and in New Jersey select nest sites surrounded by an area that excludes all houses within an average diameter of 1 km (0.6 miles; Bosakowski et al. 1993).

Plants

Five plant species found in New Jersey are federally listed under the Endangered Species Act as either Endangered (1) or Threatened (4; TESS 2000). Habitat loss is implicated in the decline of all five species:

Species	Status	Role of habitat loss in decline?
American chaffseed (*Schwalbea americana*)	E	Yes (USFWS 1995a)
Knieskern's beaked-rush (*Rhynchospora knieskernii*)	T	Yes (USFWS 1997b)
Sensitive joint-vetch (*Aeschynomene virginica*)	T	Yes (USFWS 1995b)
Small whorled pogonia (*Isotria medeoloides*)	T	Yes (USFWS 1996b)
Swamp pink (*Helonias bullata*)	T	Yes (USFWS 1990b)

As of September 1998, of the 2,117 known native plant species in New Jersey (NJDEP 1998a), 706 (one third) were listed in the State's Natural Heritage Database as State Endangered or of concern (Snyder 1998). The New Jersey Natural Heritage Network provides "Element Stewardship Abstracts" containing causes of imperilment for the following 20 plant species in the Natural Heritage Database (NJNHN 2000). Some form of habitat loss and/or associated disturbance is listed as a threat to all 20 of these species:

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Species	Listed threats	Abstract #
Bidens bidentoides	Habitat destruction	001
Botrychium oneidense	Suburban development	002
Breweria pickeringii var. caesariensis	Succession, all-terrain vehicles (ATVs)	003
Calamagrostis pickeringii	Disturbance, succession	004
Carex leptonervia	Development, succession	020
Carex mitchelliana	Habitat destruction/degradation	005
Corema conradii	Fire suppression, succession, herbivores, trampling, erosion, development	018
Coreopsis rosea	Habitat destruction, succession	006
Eriocaulon parkeri	Habitat alteration (dredging, landfill, dams)	007
Geum vernum	Succession, disturbance, herbicide	019
Juncus caesariensis	Alteration of water flow, succession, development	008
Kuhnia eupatorioides	Habitat destruction	009
Narthecium americanum	Alteration of water flow, succession, development, ATVs	010
Panicum wrightianum	Stabilization of water regime, habitat destruction	011
Platanthera integra	Succession, vandalism, alteration of water flow	012
Poa languida	Development, disturbance	013
Polygonum glaucum	ATVs, beach maintenance/reclamation	014
Potentilla tridentate	Habitat destruction	015
Pycnanthemum clinopodioides	Habitat loss, hybridization	016
Tofieldia racemosa	Succession, habitat loss, fire suppression	017

Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery	The impacts described above are consistent with habitat loss resulting in serious damage to ecosystems, threatening a high proportion of all species and resulting in major changes in communities, so an assessment of 3 would be inadequate.	4

3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure	Continuing habitat loss will result in ecosystems becoming severely impoverished but not lifeless, and the process may be reversible to some extent over long time periods, so an assessment of 5 may be excessive. This does not imply that habitat loss is not the most serious threat to New Jersey's environment.	
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	Habitat loss is an ongoing, continuous process. Some evidence (NRI 1997) suggests that the rate of habitat loss may be increasing. Recent regulatory efforts to curtail habitat loss may at least stabilize loss rates.	5
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	As quantified above, much more than 50% of the State is exposed to habitat loss.	5
	Total	100
Assessment of uncertainties in this assessment (H,M,L) and brief description	M: Uncertainties exist concerning the quantitative response of populations and ecological communities in New Jersey to current and future levels of habitat loss.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	L: The overwhelming scientific evidence points to habitat loss as the single greatest cause of species endangerment in the U.S.A. The impact assessment given here is unlikely to be altered by additional data. There is, however, a great need for ongoing quantitative analysis of loss of different kinds of habitat at the State level, to determine if rates of land use change are increasing, decreasing or stable. There needs to be more research that focuses directly on the effects of habitat loss on New Jersey plants and animals.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, !, =, ≡; where + is improvement), and brief description.	0: The underlying risks of habitat loss will remain, although prudent management may reduce its extent and effects.	

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Potential for catastrophic impacts (H,M,L) and brief description	L: Effects of habitat loss are likely to be gradual and incremental.
Link to other Work Groups (e.g., socioeconomic impacts)	Habitat loss reduces the ability of ecosystems to support human economies, for instance with pollinator services to agriculture.
Extent to which threat is currently regulated or otherwise managed	Habitat loss is identified as a significant risk requiring management attention in major land use and conservation plans applicable to the State of New Jersey, including the Interim New Jersey State Development and Redevelopment Plan (NJOSP 1999b), and the Comprehensive Conservation and Management Plans for the Barnegat Bay (BBEP 2000), Delaware (DEP 1996) and New York-New Jersey Harbor Estuary Programs (HEP 1996). As of 1998, New Jersey had 920,000 acres of permanently protected open space (all ownerships; NJDEP 1998a). The Garden State Preservation Trust Act of 1999 establishes a stable funding source to preserve 1,000,000 acres of additional open space and farmland over the next ten years. The funding to meet this ambitious goal was approved by a 1998 public vote amending the State constitution (Green Acres 2000). More than 390,000 acres of open space have been preserved through the New Jersey Green Acres Program since its inception in 1961. This land is managed by divisions of the NJ Department of Environmental Protection (Green Acres 2000). Development of inland wetlands is restricted by the Freshwater Wetlands Protection Act of 1987, which requires, as a condition of granting permits to develop freshwater wetlands, that measures be taken to mitigate adverse environmental impacts, including in some cases the creation of new wetlands to replace any lost to development (N.J.S.A. 13:9B). The New Jersey Farmland Preservation Program, administered by the State Agriculture Development Committee, has safeguarded 62,000 acres of agricultural land from development since its inception in 1981 (NJDA 2000). Development is regulated in the 1.1 million acre New Jersey Pinelands National Reserve by the Pinelands Commission. 927,000 acres of the Pinelands National Reserve constitute the Pinelands Area as defined by the New Jersey State Pinelands Protection Act of 1979. Development is most highly restricted in the 295,000 acres of the Pinelands Area classified as the Preservation Area District, and is also limited in the Agricultural Production Areas (66,200 acres) and Forest Areas (400,000 acres; NJPC 2000a). The Preservation Area District is likely to experience the least additional habitat loss of the Reserve's regions. The Agricultural and Forest Areas are likely to experience less additional loss than regions of the Reserve in which development is less restricted. From 1990 to 1998, the human population growth rate was proportionately higher in the Pinelands than in all other areas of New Jersey, but 97% of approved development applications in 1999 were in Regional Growth Areas, Rural Development Areas, and towns and villages, and not in the Preservation, Agricultural or Forest Areas (NJPC 2000b).

Walker and Solecki (1999) conclude that the Pinelands Reserve has been effective at reducing development. They reported a 7.9% increase in development in the core preservation area of the Pinelands Reserve from 1975 (before the Protection Act went into effect) to 1986, much less than the 40.5% increase in development in peripheral growth areas in the same time period.

At the Federal level, the U.S. National Park Service is involved in the management of three parks entirely or partially within New Jersey. These areas experience heavy human activity, but additional habitat loss within them is likely to be minimal:

The 67,205 acre Delaware Water Gap National Recreation Area, of which 55,162 acres are Federally owned and 12,043 acres are Non-Federal. This Recreation Area is shared between Northwestern New Jersey in the counties of Warren and Sussex, and in Northeastern Pennsylvania in the counties of Northampton, Monroe and Pike (DWGNRA 2000).

The 1,700 acre Morristown National Historical Park, which is divided into four non-contiguous sections (NPS 2000).

The 73.4 miles of the Appalachian Trail that lies within New Jersey (ATC 2000).

The Division of Parks and Forestry, NJ Department of Environmental Protection, administers 41 State Parks, State Forest and Recreation Areas, totaling 300,645 acres (DPF 2000a). Several of these lie within the Pinelands National Reserve. These areas experience varying levels of human activity, and the proportion of continuous habitat within each varies, but additional habitat loss within these areas is likely to be minimal.

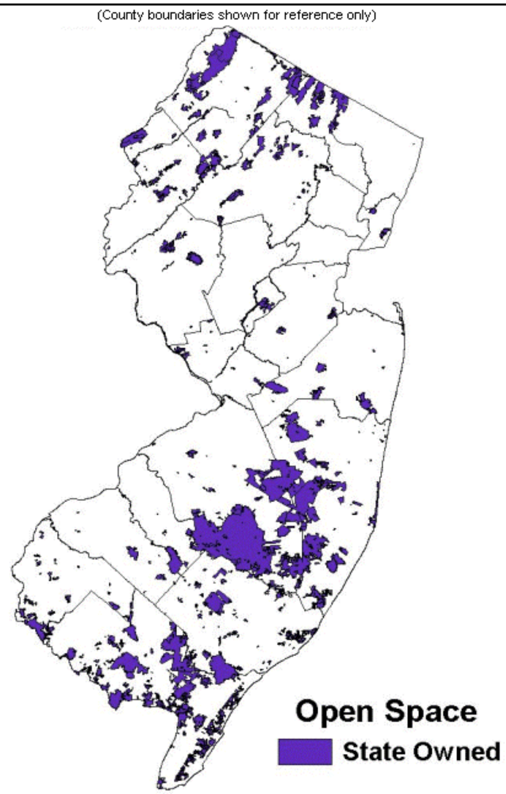
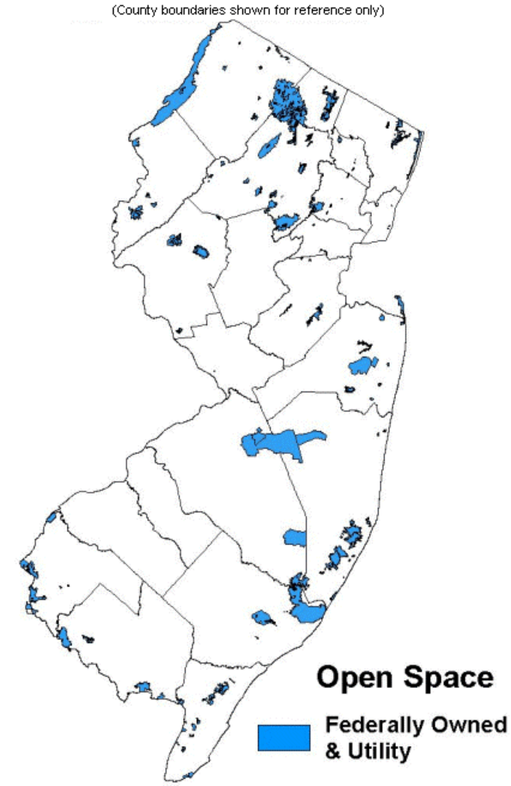
The Natural Areas System, administered by the NJ Division of Parks and Forestry, protects 42 sites totaling 31,284 acres (DPF 2000b). Many of the Natural Areas lie within State Parks and State Forests. This System is intended to protect endangered and threatened plants and animals, significant natural ecosystems and exemplary wildlife habitats. It is, therefore, unlikely that Natural Areas will experience further habitat loss.

As of May 2000, the Bureau of Land Management, New Jersey Division of Fish and Wildlife, managed 115 Wildlife Management Areas totaling 265,397 acres (BLM 2000a). In Wildlife Management Areas, fish and wildlife habitat is protected and enhanced, while providing a variety of compatible recreational and educational opportunities (BLM 2000b). Consequently, additional habitat loss in these areas is likely to be minimal.

90% of Barnegat Bay's salt marshes, and 70% of its remaining undeveloped shoreline are preserved in some type of public conservation ownership (Lathrop et al. 1999).

Approximately 45% of the Barnegat Bay watershed's interior forests are protected from development (Lathrop et al. 1999).

The following maps depict areas of open space protected under New Jersey State and Federal ownership (NJDEP 1999).

	 
Barriers to restoration	Restoring developed lands to a natural or semi-natural state would require acquisition and remediation of developed land. Due to human population pressures in New Jersey, returning currently developed land to its former state is not practical on a large scale. The major management response to habitat loss should be preventing further development.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	M
Small business industry	L
Transportation	H
Residential	H

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Agriculture	M
Recreation	L
Resource extraction	L
Government	L
Natural sources/processes	NA
Orphan contaminated sites	NA
Diffuse Sources	
Sediment sinks	NA
Soil sinks	NA
Non-local air sources incl. deposition	NA
Biota sinks	NA

Summary Statement:

Habitat loss is the conversion of land from one use or type to another, and in the context of this risk assessment, specifically means the development of wild or agricultural lands to land uses that are unsuitable for wildlife or agriculture. Researchers agree that habitat loss is the most serious environmental threat nationally. In view of the role of habitat loss in the local extinction and endangerment of a wide range of plant and animal species in New Jersey, it would be difficult to argue that habitat loss is not also the most serious environmental threat in this State. Habitat loss results in a number of ecosystem changes at many different spatial and temporal scales, reducing biodiversity and threatening ecosystem stability and functioning. Virtually the entire undeveloped area of New Jersey is at risk of habitat loss. In recognition of the undesirability of habitat loss, legislators have placed large areas of the State under protection from unregulated development. The high risk score given by this template to habitat loss is consistent with the large spatial and temporal scales at which it operates, and the severity of its impacts on ecosystems.

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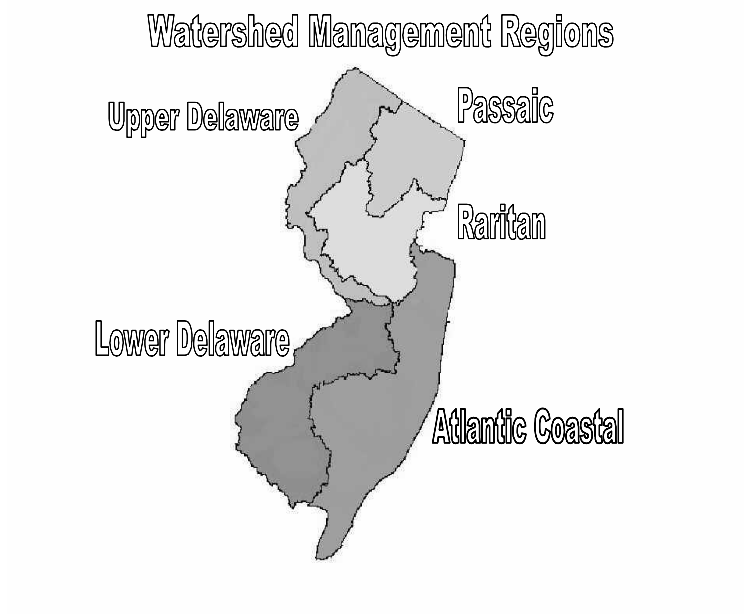
Statewide Analysis of Threat Threat = Habitat Loss

Ecosystem	**Severity Irreversibility**	**Frequency**	**Magnitude**	**Score**
Inland Waters	4	5	5	100
Marine Waters	4	5	5	100
Wetlands	4	5	5	100
Forests	4	5	5	100
Grasslands	4	5	5	100
			Total Score	500
			Average Score (Total ÷ 5)	100

Risk by Watershed Management Region

THREAT =	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	H	NA	H	H	H
Passaic	H	H	H	H	H
Raritan	H	H	H	H	H
Atlantic	H	H	H	H	H
Lower Delaware	H	H	H	H	H
Region/Watershed (secondary)					
Urban	NA	NA	NA	NA	NA
Suburban	H	NA	H	H	H
Rural	H	NA	H	H	H

H=high, M=medium, L=low, NA = not applicable


Watershed Management Regions
Upper Delaware
Passaic
Raritan
Lower Delaware
Atlantic Coastal

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Author: Tim Casey
Version: 12/07/00

Comparative Risk Project
Ecological Technical Work Group
Stressor-Specific Risk Assessment

Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Hemlock Woolly Adelgid** *Adelges tsugae* Annand (Homoptera), (McClure et al. 1996). Referred to as HWA in this report.
Description of stressor	A. tsugae *(HWA) is an aphid-like, sap-feeding, host-specific, insect pest of forest and ornamental hemlock trees (*Tsuga *spp.) (McClure et al. 1996). HWA feeds at the bases of hemlock needles (Young et al. 1995). Feeding activity causes the needles to desiccate and drop off the twig. Continued feeding prevents new growth from occurring (McClure 1987). Dieback of major limbs can occur within 2 years. The characteristic pattern of decline is general thinning of the canopy and subsequent death of branches from canopy base upward (McClure 1996). Heavy infestations can kill trees in 4 years or less (McClure 1991). Rates of decline vary between trees on a site, and between sites at landscape and regional scales (McClure 1990; Royle and Lathrop 1999a).* HWA is native to China and Japan where it is a common, innocuous, species occasionally reaching high densities on ornamental trees growing on poor sites. However, host resistance and natural predators prevent significant injury (McClure et al. 1996). First observed in western North America in British Columbia in early 1920's, in eastern North America in early 1950's in VA. Details of early infestations remain unknown, but undoubtedly result from accidental introductions (McClure 1996). HWA has a complex life cycle, with 2 generations per year; parthenogenetic; extremely virulent; unusually high fecundity (McClure 1987). HWA is dispersed mainly by wind, birds, deer and humans (McClure 1990).

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Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	The loss of hemlocks will have serious ecological consequences at various scales. Most serious is the potential loss of *T. canadensis* and *T. carolina* from North America. The defoliation and mortality of hemlock trees and forests will reduce the abundance of native species and increase the abundance of exotic species such as *Ailanthus altissima* (tree-of-heaven) and *Berberis thunbergii* (Japanese barberry) (Evans et al. 1995; Battles et al. 1999). In northern NJ, hemlock stands exist as coniferous forest patches in a predominantly deciduous forest matrix. HWA infestation has brought about a severe fragmentation of these coniferous patches (Royle 1996; Royle and Lathrop 1999b). As hemlock trees defoliate and die, they break up or tip over, causing disturbance to the forest canopy, understory vegetation and forest floor (Battles et al. 1999), and dramatically increase the amount of coarse woody debris. In drought seasons, this fuel load would increase hazard from forest fire (Koeck, pers com). Defoliation of the hemlock canopy affects nutrient cycling rates, and can result in nutrient leaching from the soil and nutrient loadings to stream water (Jenkins et al. 1999). Soil erosion may be serious on steep sites. Hemlocks provide habitat for many rare species (Benzinger 1994), and also provide cover for game and non-game wildlife (Jordan and Sharp 1967).
	Shade-tolerant hemlocks retain green foliage to the ground, thus hemlock mortality results in the loss of the vertical dimension to forest canopy, a function that cannot be replaced by other native, coniferous tree species (Benzinger 1994). Hemlock modifies stream environments, creating diverse microhabitats, and stabilizing the thermal and hydrologic regime (Lemarie et al. 1999). The cooling effect is essential for maintaining stream temperatures tolerable to brook trout (Evans et al. 1995).
Key impacts selected (critical ecological effects)	Potential loss of an important, native forest conifer; Fragmentation of coniferous forest patches, and a shift to deciduous forest and increased landscape homogeneity; Reduced abundance of native species; Increased abundance of exotic species; Increased fire hazard during dry seasons and drought years; Dramatic changes in biogeochemical processes.
Exposure Assessment	
Exposure routes and pathways considered	Passively dispersed by wind, birds, and mammals. Actively disperses during crawler stage (1-2 days after hatching) at the scale of cm on a branch. May be transported by humans on hemlock logs. Presence of bird feeders near hemlocks increases risk of spread to native hemlock stands in the vicinity (McClure 1990).
Population(s)/ecosystem(s) exposed statewide	NJ has an estimated 26,000 ac of hemlock forest (Coutros 1989). All hemlock stands have been exposed and are considered infested to some degree (Koeck, per com). As of 1994, 53% of hemlock forests in a 600mi^2 area of NJ Highlands were damaged (> 25% needle loss), and 9% were dead (Royle and Lathrop 1997). NJ state foresters observe heavier infestations along stream corridors (Koeck, pers com).
Quantification of exposure levels statewide	The US Forest Service 1999 map of HWA distribution indicates that HWA has infested natural and/or ornamental hemlocks in all NJ counties (see enclosed map). Work is in progress at Rutgers University to quantify the spatial extent, degree of defoliation, and rate of hemlock decline throughout northern NJ at the site scale (90m) using multiple dates of Landsat TM imagery spanning a 14-year period (Royle and Lathrop 1999a). Preliminary analysis indicates that defoliation has occurred in > 90% of state's hemlock forest, though the degree and rate of defoliation vary from site to site. Completion of analysis is expected by August 2000.

Specific population(s) at increased risk	All hemlocks in NJ are at risk, but hemlocks on drier sites (e.g., exposed ridge tops) may be at greater risk due to site moisture stress (Souto and Shields 1999). Preliminary analysis indicates a significant correlation between soil moisture and rate of hemlock defoliation at local scale, i.e. hemlocks on drier sites decline at a faster rate (Royle and Lathrop 1999a). This pattern indicates that, once infested, hemlocks on drier sites are at increased risk of defoliation and mortality.	
Quantification of exposure levels to population(s) at increased risk	Included in "Quantification of exposure levels statewide" (see above).	
Dose/Impact-Response Assessment		
Quantitative impact-assessment employed	The NJDEP, Bureau of Parks and Forestry, established 11 hemlock monitoring plots, mainly in the northern region (Ward et al. 1992). All are currently infested (Koeck, pers com). The National Park Service has established permanent plots in both NJ and PA. Despite low to moderate HWA infestations over the past 5 years, individual trees in these plots are relatively healthy (Battles et al. 1999).	
Risk Characterization		
Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		Score

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Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduced Short time for recovery 2 – Ecosystem exposed but structure and function hardly affected 1 – No detectable exposure	Hemlock defoliation is irreversible. If the HWA population is eliminated from a tree, new growth may continue in upper canopy and on unaffected branches. Infested trees rarely recover. Success in predator-release programs may reduce the risk to currently healthy trees. However, HWA infestation is expected to be a chronic problem.	4

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Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 – Often and increasing 4 – Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)	HWA continues to infest and re-infest hemlock trees throughout the state; Effects are expected to continue and escalate.	5
Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted	HWA is found in all New Jersey counties on native and/or ornamental hemlocks; Dense HWA populations are local in distribution, with heavy damage and mortality occurring in some stands, e.g., Sparta Glen area. Satellite imagery from 1984 to 1998 indicates that defoliation is occurring throughout the native stands, but rates vary within and between stands; (see "Quantification of exposure levels statewide").	4
	Total	80
Assessment of uncertainties in this assessment (H,M,L) and brief description	(Low) Although majority of hemlock research has been conducted outside of NJ, the results are reliable and applicable to NJ.	
Potential for additional data to result in a significant future change in this risk estimate (H,M,L) and brief description. (Data Gaps; highlight significant data needs)	(High) Very little is known about the ecological effects of HWA infestation, though many research efforts are underway throughout the northeast (see McManus et al. 2000). Data gaps in NJ include: Short and long term monitoring studies of the effects of hemlock defoliation on terrestrial and aquatic communities, biodiversity, biogeochemical cycling and ecosystem functions. Spatially explicit models incorporating HWA epidemiology, weather and climate data, and site and landscape factors predicting hemlock vulnerability are important for natural resource management. Also needed are studies of the effectiveness of predator release programs currently underway in NJ.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, –, =, ≡ where + is improvement), and brief description	++ If exotic predators currently being introduced into NJ hemlock stands prove successful in controlling HWA populations, the risk to currently healthy stands (e.g., northwestern Sussex County) may be significantly reduced. However, there is little hope for New Jersey stands that are now heavily infested and experiencing > 50% defoliation.	
Potential for catastrophic impacts* (H,M,L) and brief description (*Short-term drastic negative impacts having widespread geographic scope)	(High) Unless stopped through biological, chemical, or other means (e.g., tree removal), HWA infestation will undoubtedly lead to extirpation of native hemlocks from the state and neighboring region, accompanied by serious and dramatic ecological impacts.	
Link to other Work Groups (e.g., socioeconomic impacts)	Hemlocks are highly valued for their beauty, and more than 270 cultivars are used in the landscape industry. The cost of tree removal and/or treatment can be prohibitively expensive. Natural hemlock stands are important, aesthetic, natural features in municipal, county, state and national parks, forests and natural areas.	
Extent to which threat is currently regulated	No regulations in NJ. Transport of hemlock logs into some New England states is illegal.	

Barriers to restoration	HWA will continue to spread back and forth between untreated ornamental plantings and native trees, making restoration difficult or impossible.
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources	
NJ Primary Sources	
Large business/industry	L-M. Hemlock is not harvested for timber, pulp, etc., in NJ, per se. However, the planting of hemlock continues in the horticulture/landscape industry. Such plantings will serve as both sources and sinks for HWA infestation.
Small business industry	L-M. See "large business/industry" above.
Transportation	Low to none.
Residential	(Mod) Continued spread from infested ornamental trees. Bird feeders may increase the probability of HWA dispersal from residential plantings to native stands via birds (McClure 1990).
Agriculture	(Mod) See "large and small business/industry". Some nursery operations are still growing hemlocks for sale. If nursery trees are untreated, they could be infested, thus facilitating HWA dispersal.
Recreation	(Low, but possible (e.g., hikers come into contact with infested foliage and inadvertently carry the crawlers to uninfested stands).
Resource extraction	Low to none. (See business/industry)
Government	NA
Natural sources/processes	High. Infested, native trees will serve as sources of HWA to other native trees and to ornamental hemlocks, from local to regional scales.
Orphan contaminated sites	High. Infested, isolated stands, though relatively distant from other stands, still serve as a source of HWA.
Diffuse Sources	
Sediment sinks	NA
Soil sinks	NA
Non-local air sources incl. deposition	NA
Biota sinks	NA

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Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	N/A	N/A	N/A	N/A
Marine Waters	N/A	N/A	N/A	N/A
Wetlands	5	4	3	60
Forests	5	4	5	100
Grasslands	5	2	3	30
			Total Score	190
			Average Score (total score ÷ 5)	38

Risk by Watershed Management Region

THREAT = Hemlock Woolly Adelgid	ECOSYSTEM				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	N/A	N/A	M	H	L-M
Passaic	N/A	N/A	M	H	M
Raritan	N/A	N/A	M	H	L-M
Atlantic	N/A	N/A	M	H	L-M
Lower Delaware	N/A	N/A	M	H	L-M
Region/Watershed (secondary)					
Urban	N/A	N/A	M	H	M
Suburban	N/A	N/A	M	H	M
Rural	N/A	N/A	M	H	M

H=high, M=medium, L=low;

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New Jersey Comparative Risk Project
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Risk Assessment Framework	Findings
Hazard Identification	
Stressor	**Inadvertent Animal Mortality**
Description of stressor	The diamondback terrapin (*Malaclemys terrapin*) is a medium sized, brackish water turtle of the family Emydidae. They possess a wide range of colors and markings of perhaps any turtle in the world. Their shells have a series of concentric grooves and ridges, or have patches of light and dark markings, which range from gray to brown to black to green to yellow to orange. Their body may be of uniform color or it may be decorated with a variety of spots, and/or stripes. One trait is characteristic of all diamond backs, and that is their deeply grooved diamond shaped scutes. Their heads and legs are often spotted or flecked. Diamondbacks are strong climbers and have webbed feet enabling them to swim fast. Terrapins are sexually dimorphic. Females grow much larger than males and their shells range from six to nine inches when full grown. The male shell does not exceed five inches. The male tail is always much longer and thicker than those of the bigger females, however, the females have larger heads which adds to their bulkier look. Other differences exist but they are subtle. Terrapins are broad-spectrum carnivores, so they are at the top of the salt marsh food web. They feed on mussels, clams and snails, all of which they crush in their powerful jaws. Fiddler crabs are their favorite food, however they will also eat minnows. Diamondbacks are considered more of a predator than a scavenger because of their strong beak and crushing jaws (they do not have teeth). Diamondbacks are the only US turtles that inhabit estuaries and saltwater marshes where the salinity comes close to that of the ocean. It is in this type of environment that these turtles thrive for it has been proven that the diamondback is one of the most physically variable of the seven turtle sub species. They prefer unpolluted tidal areas and therefore are good indicators of healthy wetland systems. The diamondback may live to age 50. By age 4 the male is considered mature and by age 12 the female is mature. Mating occurs in May. Female terrapins store sperm and thus can produce fertilized eggs up to four years after mating. However, gravid females venture out of the water and marshes to lay their eggs on dry land during the egg laying season, June and July. In New Jersey, a nesting terrapin will lay between 8 and 12 eggs in a given nest. A female may lay at least 2 clutches of eggs each nesting season. Once the eggs are in the nest, the female's role is complete.

	Hatching occurs between August and October. Sex of the hatchling is dependent upon the temperature of the nest. A higher nest temperature produces more females and vice versa. Once the hatchling emerges it is only one inch long and on its own. Only 1-3% of the eggs laid produce a hatchling, and survivorship of these hatchlings is low. Most of the eggs are dug up and eaten by predators, which include herons, foxes, skunks, raccoons and crows. Those hatchlings that do survive are then subject to predation by crabs, fish, and birds such as gulls and bald eagles. Studies show that terrapins may remain in a small area for most of their life, and are quite docile. They stay close to their natal beaches and waterways and are not likely to repopulate in other areas on their own.
Stressor-specific impacts considered: Biological integrity Biodiversity Habitat/ecosystem health Ecosystem function	In New Jersey and throughout the terrapin's geographic range from Massachusetts to Texas, terrapins have had a poor history of interactions with humans. As a result, the once abundant terrapin populations have become significantly reduced in numbers. However, a new and different kind of threat has developed for these terrapins. That is a large-scale loss and degradation of salt marsh habitat. Vast stretches of prime nesting habitat-sand dunes, which are now coastal barrier beach island resort communities are gone forever. Other tributaries and creeks that once supported healthy populations are now devoid of terrapins due to fishing mortality (both directed and unintentional in crab pots) and habitat loss. Habitat loss for some river systems is known to be 75% due to "hardened shorelines", i.e., bulkheads and revetments. Unable to nest in their traditional areas, terrapins have to seek alternative nesting sites above the high tide. Occasionally in these water front communities, a terrapin in search of a nesting beach will end up in someone's garden or mulch pile laying their eggs. Unfortunately, searching for a nesting beach has also resulted in fatality. Terrapins have turned to the embankments of roads crossing adjacent to salt marshes for new nesting sites. Large numbers of female terrapins are killed annually by vehicular traffic during the nesting season.
Key impacts selected (critical ecological effects)	Natural predators such as foxes, crows, raccoons, humans, and nature itself are increasing near terrapin habitat. Here one could say that nature, and, we humans are considered major predators. For the ideal nesting habitat for the terrapin is diminishing by natural erosion, development, and shore erosion protection measures. For example, some of the natural grasses planted to slow the assassin process actually ruin terrapin nests by entrapping them in the root system or by piercing their eggs. All of the above result in inadvertent mortality of the terrapin and their eggs.
Exposure Assessment	
Exposure routes and pathways considered	Exposure pathway of the terrapin will be identified in this section as their detrimental exposure to humans our associated technologies and lifestyles. Because their geographic distribution coincides with densely settled coastal areas, humans have long exploited terrapins. For example: It has been noted that beach cleaning techniques crush the terrapin nest. Tire tracks from vehicles used on the sand pose a hazard to hatchlings for they get trapped in the tire tracks and can die before reaching the water. Also, increased boat traffic is a threat, as the terrapin cannot out swim a speedboat. However, a major threat to the terrapin population is the crab pot. The crab pot is fished in swallow waters and has contributed to the demise of the terrapin population due to fishing mortality, from both directed and unintentional in crab pots. Crab pots were introduced to industry in the 1940's, which was and still is commercial gear which use was limited to those with a commercial crabbing license. In this case if the terrapin wonders into the pot and the pot is checked routinely and in time, the terrapin while survive. However, today waterfront property homeowners, and non- commercial crabbers use these crab pots. Here is where the terrapin is unintentionally captured and drowned.
Population(s)/ecosystem(s) exposed statewide	Severe over hunting rapidly depleted coastal salt marshes of terrapin populations found along the Atlantic Coast of the United States. The affected area ranges from Cape Cod Massachusetts, being the northern end of the terrapin range to the Florida peninsula and keys to the Gulf Coast of Texas.

Quantification of exposure levels statewide	Conservative numbers suggest that tens of thousands of diamondbacks drown in these traps annually, resulting in the deaths of nesting females and the loss of viable eggs. "A species cannot continue to survive without adequately replenishing its population" (Terrapin Conservation).
Specific population(s) at increased risk	Gravid female terrapins due to traffic mortality and juvenile and male death due to the use of crab pots because of their smaller size.
Quantification of exposure levels to population(s) at increased risk	In New Jersey (NJ), as of the summer of 1995, the number of road kill terrapins has decreased over the past six years from more than 1,000 to under just 500 in 1994. However, these numbers are not as favorable as they seem. Statistics show that the declining numbers actually indicate a diminishing terrapin population. A NJ study conducted by the Wetlands Institute of Stone Harbor estimates that 1,000 to 1,500 female terrapins are killed throughout the state on the road each year. (NJ Outdoors, Summer 1995-Terrapins, Tires and Traps). The Institute also estimates that tens of thousands of terrapins of all sizes and both sexes drown each year in the 50,000 crab pots (traps) deployed in NJ's coastal waters.
Dose/Impact-Response Assessment	
Quantitative impact-assessment employed	In an effort to combat the decline of the terrapin population in NJ the Wetlands Institute of Stone Harbor started a program called "Life After Death". This program involves rescuing undamaged and potentially viable eggs from fresh road kill. The eggs are incubated at the terrapin farm at Stockton State College in Pomona NJ with a hatching success rate ranging between 30-50% of the eggs that are retrieved. When the time is right these hatchlings are released back to the salt marshes. Many of these hatchlings reach reproductive age and contribute to the perpetuation of their species. " If all the hatchlings survived to adulthood, they would replace only half of the mature females killed annually by motor vehicles" NJ Outdoors, Summer 1995-Dr. Roger Wood). This program only helps to slow down the rate at which the terrapin population is declining. As a result of the estimated loss due to crab pots (traps) the Wetlands Institute of Stone Harbor developed an in expensive device with federal funding and the help of the NJ Division of Fish and Game, to prevent terrapins from entering the pots (traps). This device is called a "Bycatch Reduction Apparatus (BRA). A study by the Institute shows that this device has been successful in preventing 90 percent of all terrapins from entering the crab pots (traps). The use of this device becoming widespread in NJ and in other Atlantic and Gulf Coast states has the potential for saving a large number of terrapins. With terrapin numbers declining year after year, this device is critical in helping to restore the terrapin population, here in NJ and along the Atlantic Coast.
Risk Characterization	

Risk estimate(s) by population at risk Risk Score = (Severity/Irreversibility) x (Frequency) x (Magnitude)		**Score**
Assessment of severity/irreversibility 5 - Lifeless ecosystems or fundamental change; Irreversible 4 - Serious damage: • many species threatened/endangered • major community change • extensive loss of habitats/species Long time for recovery 3 - Adverse affect on structure and function of system: • all habitats intact and functioning • population abundance and distributions reduce Short time for recovery 2 - Ecosystem exposed but structure and function hardly affected 1 - No detectable exposure		4
Assessment of frequency of effect(s) (list definition for each category, e.g., rare = 1/decade) 5 - Often and increasing 4 - Often and continuing 3 – Occasional 2 – Rare 1 - Possible in the future 0 – Unlikely (or 0.1)		3

Size of population(s) and/or extent of the State/habitat affected (magnitude) 5- >50% of the State/population impacted 4- 25-50% of the State/population impacted 3- 10-25% of the State/population impacted 2- 5-10% of the State/population impacted 1- <5% of the State/population impacted		5
	Total	60
Assessment of uncertainties in this assessment (H,M,L) and brief description	M-roadkill and inadvertent terrapin morality is difficult to document due to its labor intensive practices and expensive operating costs.	
Potential for additional data to result in a significant future change in this risk estimate (H, M, L) and brief description. (Data Gaps; highlight significant data needs)	H-continuing regulations and on going studies will fill in data gaps that now exist and result in better protection for the terrapin.	
Potential for future changes in the underlying risk from this stressor (+++, ++, +, 0, ! , =, ≡; where + is improvement), and brief description.	++ By using the Bycatch Reduction Apparatus in crab pots (traps)	
Potential for catastrophic impacts (H,M,L) and brief description	H-If regulation and protection measures are not maintained, upgraded or complied with. Without preventive efforts, stress on the terrapin population will continue to be severe, and there is danger that this species may once again suffer a population crash similar to that they suffered in the e 1800's through the early 1900's.	
Link to other Work Groups (e.g., socioeconomic impacts)	L- Terrapins are no longer considered a highly desirable exotic food known as a gastronomic delicacy.	
Extent to which threat is currently regulated or otherwise managed	L-Environmental legislation, starting with the Wetlands Act 1971 and clean water regulations have ended the filling in of the marshes and pollution of the water. However, it was too late to protect habitat vital to the terrapins. Although terrapins are offered some degree of protection in every state they are found. In NJ, terrapin regulations are among the most stringent of all. Even though terrapins are classified as game species, terrapins can only be taken from November 1 to March 31. This coincides with their hibernating season when they are hard to find. Also, terrapins must be a minimum of five inches long and no traps, pots, nets…can be used to capture them. NJ also prohibits collecting and destroying terrapin eggs. During the remainder of the year, terrapins are absolutely protected for it is illegal to hunt or catch them in any manner, and there is a $25 fine for each unhatched egg found in anyone's possession. Unfortunately, this prohibition is difficult to enforce. NJ does require a no cost license for non commercial crab pots (over 10,000 licenses have been issued).	
Barriers to restoration	H-Human exploitation	
Relative Contributions of Sources to Risk (H,M,L); include any information/details on sources		

NJ Primary Sources	
Large business/industry	NA-no longer considered as an exotic food
Small business industry	H-crabbing industry
Transportation	H-motor vehicle roadkill
Residential	M-humans exploit terrapins as pets
Agriculture	NA
Recreation	M-humans collecting terrapin eggs to hatch and terrapin shells for show
Resource extraction	H-commercial real estate development of the coast and salt marshes
Government	NA
Natural sources/processes	M-animal predators (source of food)
Orphan contaminated sites	NA
Diffuse Sources	
Sediment sinks	NA
Soil sinks	NA
Non-local air sources incl. Deposition	NA
Biota sinks	NA

Summary Statement: During the late 1800's through the late '20s of this century, the diamondback terrapin populations were greatly depleted in the wild. This was mainly due to harvesting for the gourmet food market. For this reason, several states acted in a timely manner to protect them from complete annihilation, and the diamondback terrapin soon recovered in the wild for their numbers increased significantly. This recovery was dramatic, and the states lifted their protective status and commercial trade in diamondbacks was again allowed. Fortunately, diamondback terrapin meat was no longer in demand so the terrapins were able to thrive survive and reproduce in their natural habitats…until recently.

Today, the biggest threats come not from the palate, but from tires, crab traps and real estate development. Diamondback terrapins now must contend with urban progress as well as the effects of commercial crabbing. Habitat destruction, roadkills, pollution and mass drowning in crab traps are now threatening the status of the diamondback terrapin population once again throughout their range. The ecology and behavior of terrapins, coupled with increasingly intensive human use of coastal regions, inevitably puts these inoffensive turtles in harm's way.

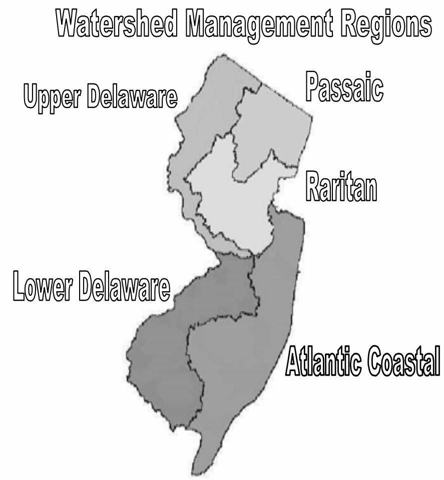
Without preventive measures, stress on the terrapin population will continue to be severe, and there is danger that this species may once again suffer a population crash similar to the one it experienced in the late 1800's. However, army people with information about the sources of its mortality may help to put them back on the road to recovery

Issue: Inadvertent Animal Mortality
Author: Santiago/Ezze/Dobi
Version: 07/24/00

Threat = Inadvertent Mortality of Diamondback Terrapin (turtle)

Statewide Analysis of Threat

Ecosystem	Severity Irreversibility	Frequency	Magnitude	Score
Inland Waters	NA	NA	NA	NA
Marine Waters	3.5	4	5	70
Wetlands	3.5	4	3	42
Forests	NA	NA	NA	NA
Grasslands	NA	NA	NA	NA
			Total Score	112
			Average Score (Total score ÷ 5)	22.4



Risk by Watershed Management Region

THREAT = Inadvertent mortality – Diamondback	*ECOSYSTEM*				
Watershed Management Region	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Upper Delaware	NA	NA	NA	NA	NA
Passaic	NA	M	M	NA	NA
Raritan	NA	M	M	NA	NA
Atlantic	NA	H	H	NA	NA
Lower Delaware	NA	H	H	NA	NA
Region/Watershed (secondary)					
Urban	NA	M	M	NA	NA
Suburban	NA	M	M	NA	NA
Rural	NA	H	H	NA	NA

H=high, M=medium, L=low, NA = not applicable

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